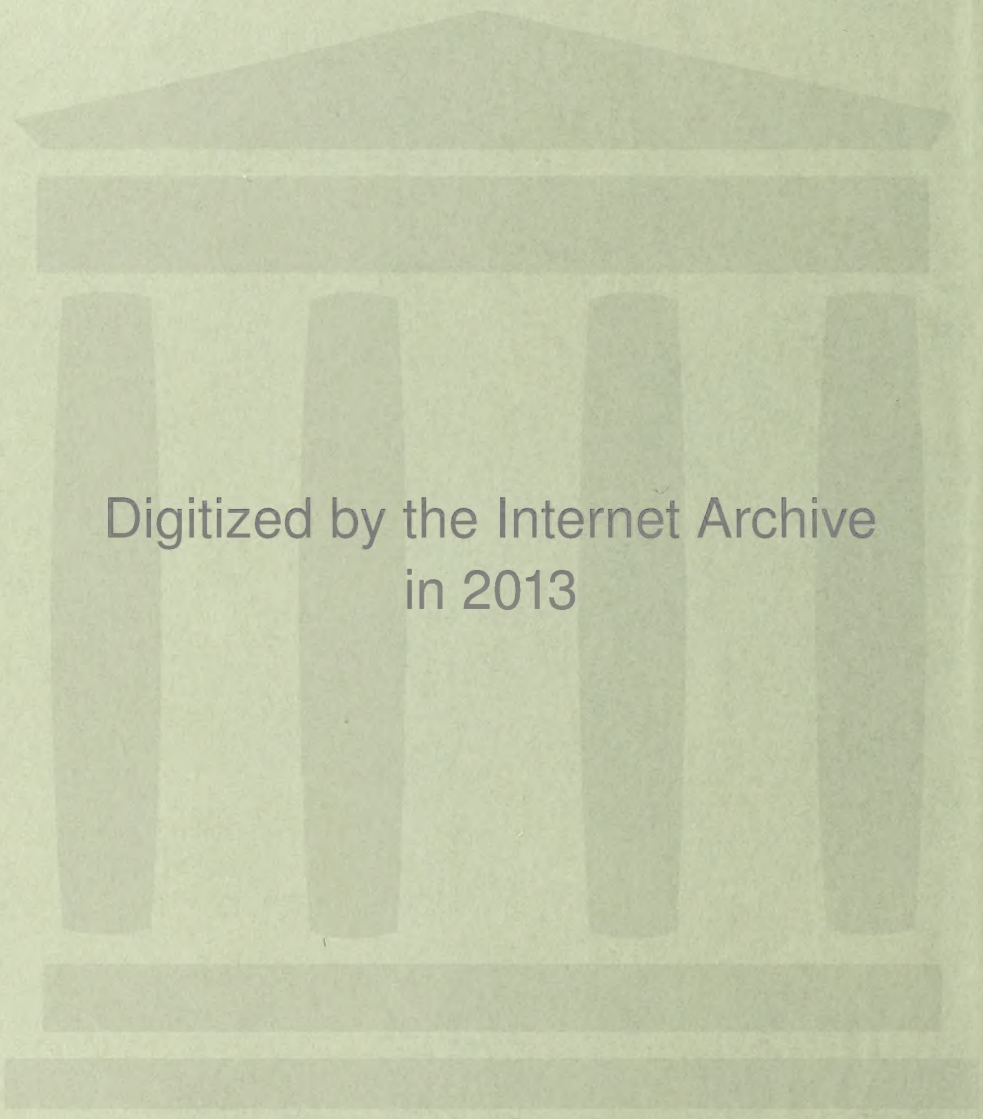

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Vegetative Propagation of Slash Pine

by

François Mergen

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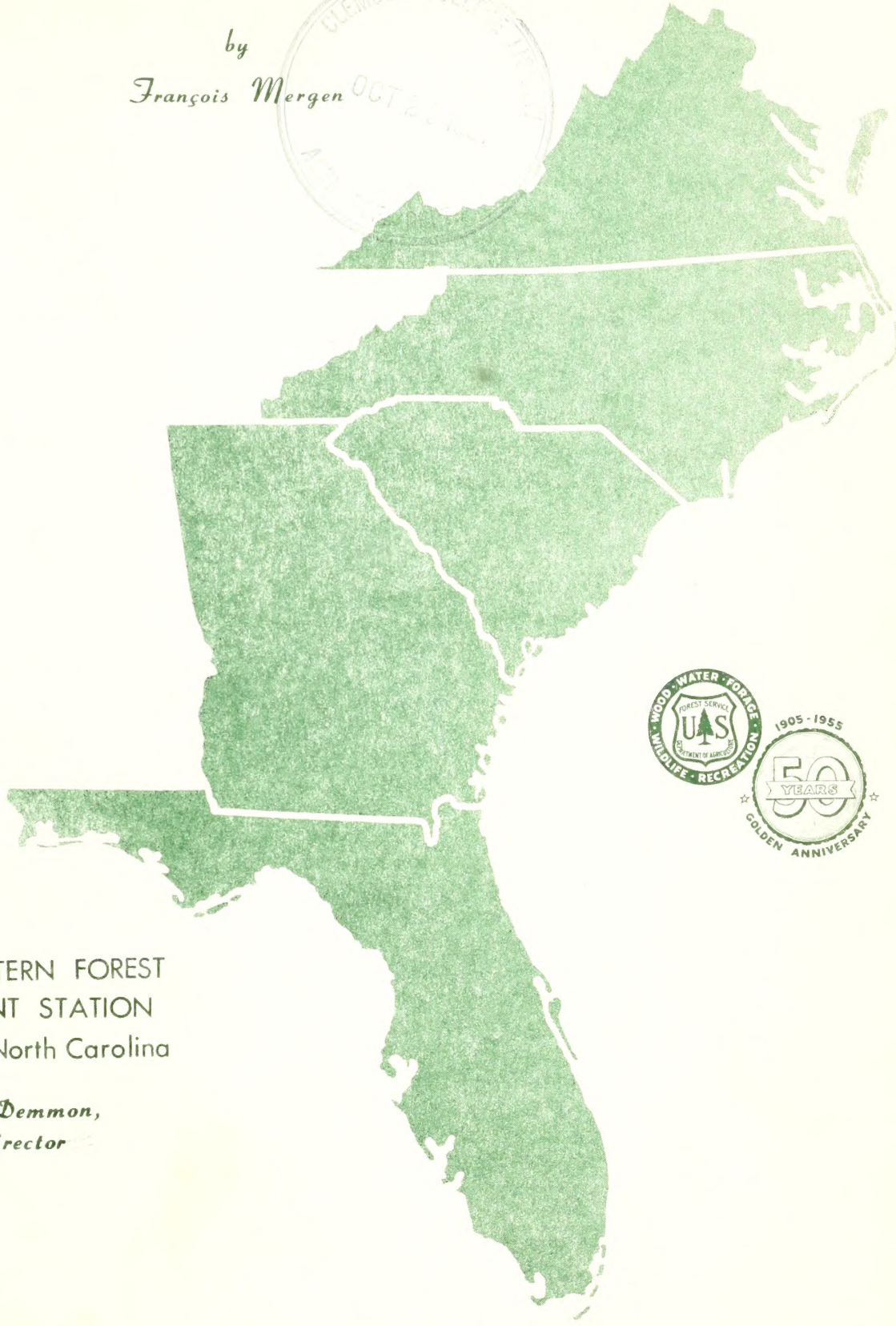

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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Subsequent to writing this paper, Dr. Mergen accepted an appointment as Assistant Professor of Forest Genetics, Yale University, John A. Hartford Program in Forest Biology, Valhalla, N. Y.

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VEGETATIVE PROPAGATION OF SLASH PINE

By
François Mergen
Lake City (Fla.) Research Center
Southeastern Forest Experiment Station

INTRODUCTION

Slash pine (Pinus elliottii Engelm.) is considered one of the most important forest tree species in the United States. Its wood is suitable for a great variety of products, and the living tree is the largest source of oleoresin in the United States. Slash pine is an aggressive invader of old fields and reproduces satisfactorily under proper management practices. Under the present reforestation program in the South the bulk of seedling stock is slash pine. During the 1953-1954 planting season, over 260 million slash pine seedlings were planted. In the State of Florida alone, 70 million slash pines were made available from public and private nurseries during the 1953-1954 planting season. This large-scale planting program depends on an adequate supply of seed.

Seed buyers are under pressure to obtain sufficient quantities of seed, and at present, insufficient attention is paid to seed origin, even though nurserymen are well aware of the importance of heredity in slash pine seed.

The place of genetics in forestry is now well recognized. The best time to apply genetic principles is during the regeneration period when outstanding trees can be selected as parents for the trees in the new stands. The extensive planting program, along with short rotations for merchantable timber products, makes slash pine an excellent species for research in forest genetics. The vast reforestation program presents great opportunities to apply genetics to forestry. It is the task of the forest geneticist to work toward improved planting stock by developing methods to produce seed of the highest possible quality. He can begin by working with the wide natural variations occurring in forest trees. He can use selected trees directly, or work toward better strains by recombining desirable characters through controlled pollination. Once superior strains of slash pine have been located or developed, clonal plantations or seed orchards will be established to produce superior seed in large quantities. This final step in a tree improvement program must be preceded by numerous studies, such as the location and selection of trees for breeding and the estimation of the genotype and breeding characteristics of selected trees. Selection in the forest is based on the phenotypical appearance of the tree; its hereditary qualities can be estimated only by observing its progeny or the growth of rooted cuttings, branches, or grafts. If the superiority of an individual tree or strain has been established, these can be multiplied vegetatively and seed orchards can be established by grafting scions on wildling plants.

In 1941, a forest tree improvement program was initiated at the Lake City, Florida, Research Center, now part of the Southeastern Forest Experiment Station. Through the application of genetic principles, its objective was to develop strains of pine which would produce large yields of naval stores products. At first, selection and breeding were carried out with that objective in mind. Since then, primary emphasis has been placed on fast growth and good form.

Because vegetative propagation is an essential part of this program, a great deal of research has been devoted to various aspects of vegetative propagation techniques. Good progress was made but, owing to the size of the problem, much additional research is needed to supply answers to the various phases of asexual

propagation. The object of the present investigation was to determine some of the factors which are of importance in rooting and grafting [1/] slash pine, and to suggest workable methods for vegetative propagation.

THE PLACE OF VEGETATIVE PROPAGATION IN FOREST TREE IMPROVEMENT PROGRAMS

In vegetative reproduction, plants are multiplied without fusion of the male and female reproductive cells. This type of asexual reproduction assures progeny with hereditary characteristics identical to those of the parent. In vegetative propagation, new plants are established as the result of somatic cell mitosis of the meristems, as compared to meiotic division which is associated with sexual reproduction. This is the important factor which permits rooted cuttings to develop true to form without any different or new traits from a second parent. The degree of heterozygosity does not exert any influence in vegetative regeneration, and the propagules of a particular plant will be homogeneous in their genetic make-up unless a mutation occurs. Thus, the vegetative method of propagation is a helpful tool in multiplying or preserving valuable germ plasm and in estimating the genotype of selected trees. When these propagules are outplanted on different sites, they demonstrate whether or not a certain trait is the result of environmental influence or of the plant's genotype.

Vegetative propagation has always been of great ecological significance to forestry. Some of the pioneer species form pure stands by means of vegetative propagation, and many aspen stands have originated from one single tree. New shoots sent out from the root-system of a harvested tree are the basis of many coppice silvicultural systems. Cuttings are used to establish basket willow plantations. These important aspects are based on the natural ability of the species to reproduce themselves vegetatively under wide physiological and environmental conditions. Induced vegetative propagation of forest trees received little attention until some 15 years ago, when foresters with foresight started to produce better trees for reforestation. It soon became obvious that this method of reproduction was of paramount importance to the success of their programs. Different methods had to be developed for the various species. In spite of many years of intensive research both in this country and abroad, there still are no reliable methods for vegetative propagation of many of our conifer species. This is especially true of slash pine.

A tree with desirable characteristics can be increased many fold and without delay by the propagation of rooted cuttings (Snow and Duffield, 1940). Farmers on Long Island have maintained the shipmast locust as a pure strain by this method (Detwiler, 1937). This strain of locust does not produce a good seed crop and the custom has been to propagate it vegetatively by digging sprouts in an established grove and outplanting them (Schwingle, 1937). The possibility of developing rust-resistant pine strains by rooting cuttings from resistant trees was mentioned by Mirov (1937; 1938). Schreiner (1937) stressed the fact that tree breeders can utilize and multiply without delay excellent individuals that may be produced at the various stages in

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1/ The following results on the grafting studies are available:

F. Mergen. Grafting succulent slash pine scions. Southeastern Forest Expt. Sta. Research Note 59. 1954.

F. Mergen. Heteroplastic micrografting of slash pine. Southeastern Forest Expt. Sta. Paper 47, 17 pp. 1954.

F. Mergen and H. Rossoll. How to root and graft slash pine. Southeastern Forest Expt. Sta. Paper 46, 22 pp. 1954.

F. Mergen. Anatomical study of slash pine graft unions. Quart. Jour. Fla. Acad. Sci. 17(4): 237-245. 1954.

F. Mergen. Grafting slash pines in the field and in the greenhouse. Publication pending in Jour. Forestry.

the breeding work. Jacobs (1939) felt that vegetative reproduction by cuttings offers definite possibilities of producing planting stock on a large scale for reforestation work in Australia. He considered it as the method which offered the greatest possibility of improving the general quality of the forests. Mitchell et al. (1942) directed all the research in the vegetative propagation of selected naval stores pines toward the development of effective techniques sufficiently simple for use under large-scale nursery conditions.

Selection of "superior" forest trees is usually carried out over large areas. Evaluation by comparison with the surrounding stand makes selection difficult. Site conditions and climatic factors vary with the various stands, and a true comparison between the selected trees is not possible. By vegetative propagation these trees can be multiplied, brought together, and outplanted in test plantations on various sites to compare their growth habits.

Syrach Larsen, a pioneer in the field of forest genetics, stressed the importance of vegetative propagation in a talk given to the 1936 International Congress of Silviculture in Budapest (Larsen, 1936). He urged foresters to consider vegetative propagation not only for the purpose of preserving the most luxuriant trees, but also to establish seed plantations to supply seed for practical use. In a later publication (Larsen, 1937), he elaborated on the usefulness of vegetative propagation especially as a means of estimating the genotype of certain individuals and obtaining information on the effect of certain climatic factors on the growth pattern of forest trees. Swedish tree breeders have established field trials with rooted cuttings from selected trees to test their genotype (Johnsson, 1950), and in Britain, Matthews (1952) brought selected individual forest trees into one central place by means of rooted cuttings and grafts.

During the period between 1942-1948 this method was used to assemble rooted cuttings from selected high-gum-yielding slash pines at Olustee, Florida. These cuttings were collected from trees growing in various parts of the naval stores belt. They were outplanted on a uniform site to protect the germ plasm of the selections and also to obtain an estimate of the genotype of these trees. Viscosity of oleoresin from cuttings compared with that from the parents showed that viscosity is a fixed character in slash pine (Mergen, 1954).

Vegetative propagation has also been resorted to by Chiba (1952) to facilitate his controlled pollination work with Cryptomeria. He collected cuttings from selected trees before the ovulate flowers were ripe. Flower buds on the cuttings developed normally, and successful controlled pollinations were carried out.

As early as 1831, DeLamarre proposed to graft scions from superior species on trees in inferior stands to establish seed trees and thus assure reproduction from these superior trees (Mirov, 1940). This method of propagation was not resorted to until forest tree breeding programs were started in various countries a century later. At the present time the grafting method of propagation is probably the most important one for forest tree breeders.

The establishment of seed orchards to supply forest tree seed of tested stock is the approach used in most forest tree improvement programs. These seed orchards are stands raised and managed exclusively for the production of forest tree seed. They can be established in three ways, by the outplanting of seedlings arising from controlled pollination, by rooted cuttings, or by grafted stock.

Slash pine seedlings resulting from controlled pollination require 10-20 years before they start producing seed in large quantities. Rooted slash pine cuttings start to flower at an early age (Mergen, 1953a), but this method of propagation will require additional research before a relatively large number of the selected trees can be multiplied by rooted cuttings.

With our present state of knowledge, grafting scions of proven stock is the best way to establish seed orchards for pines. Grafting of forest trees often gives rise to abundant flowering (Lindquist, 1948) and there is a great time-reduction in flowering following grafting (Zobel, 1953). Zak (1953) estimated that grafted pines can be expected to produce sizeable cone crops 8 years after establishment.

Seed orchards have been established in many countries. The Scandinavian countries are leaders in this field. At many of the tree breeding stations in Sweden and on the continent, grafted material has been used to great advantage in controlled pollination work (Hitt, 1952). Johnsson (1947) reported that in Sweden 10,000 grafts are made each year for seed orchard establishment. In 1949, the first grafts were made in Finland, and by 1953 a total of over 25,000 grafts had been made (Anonymous, 1953). The Canadian forest tree breeders started grafting white pine in the spring of 1947 and as a result of their expanded program several thousand grafts have been made (Heimburger, 1951). Marquardt (1951) considered the establishment of seed orchards from insect-resistant trees as a possible approach to obtain Douglas-fir resistant to Adelopus needle-cast fungus.

Besides being of great importance in the establishment of seed orchards, grafting is used in many facilitating studies. Mirov (1940) treated ponderosa pine seed with colchicine to induce polyploidy. Most of the seedlings died shortly after germination because the chemical treatment destroyed the radicle. He saved some seedlings by grafting them on healthy root stocks and thus was able to observe their subsequent development.

Bingham, et al (1953) used vegetative propagation by grafting to confirm apparent resistance to blister rust in their white pine field selections.

The Texas forest tree improvement program uses twin grafts to assess the importance of the genetic factor in determining the specific gravity of loblolly pine (Folweiler, 1953). A scion from a tree having a high specific gravity and a scion collected from a tree with low specific gravity are grafted on the same root stock to eliminate the effect of environment.

As early as 1930, the multiplication by budding of rubber trees with a high yield was a standard practice to obtain stands having uniformly high production (Summers, 1930).

Mirov (1951) was able to induce early flowering in five different pine species by grafting their seedlings on mature ponderosa pine trees. The flowering started at the beginning of the third growing season, which was 2 years after the seedlings were grafted. Grafted slash pine seedlings, however, did not produce flowers.

Jackson and Zak (1949) used a variety of grafts on young and adult shortleaf pines to test the virus hypothesis of the littleleaf disease.

This review indicates that vegetative propagation is an indispensable tool in forest tree improvement programs. Such propagation not only makes possible the multiplication of trees without changing their genetic make-up but is valuable in estimating their genotype, in bringing together in one location desired plant material for seed orchards, and in preserving selected tree plasm and thereby prolonging the life of trees. In addition to these considerations, vegetative propagation permits one to transplant a scion onto a root stock which can survive under particular conditions, change a dioecious tree into a monoecious tree, propagate bud mutants, induce flower formation, study virus transmittal, and establish propagules of one individual in distantly located areas. Vegetative propagation has proven its value in a large number of approaches, and with the expansion of research programs it will probably find application in other new fields.

With our present knowledge there are few forest tree species which can be economically propagated by cuttings. Much research is needed in this field. The Canadian tree breeding program has given a great deal of attention to the vegetative reproduction of forest trees (Johnson, 1945). Farrar (1947) reporting on the Canadian work, stated that results of the attempts to propagate selected individual pines by cuttings were disappointing, and that they indicate the urgency of further work in vegetative propagation techniques.

GENERAL OUTLINE OF THE INVESTIGATION

The investigations described in this report were conducted at the Lake City, Florida, Research Center. They were part of a comprehensive forest tree improvement program which has as its objective the development of better strains of slash pine for reforestation work. In the past, the lack of suitable rooting and grafting methods for slash pine hindered the progress of the project. Thorough study of the problem was essential if the project was to bring satisfactory results.

The investigations were separated logically into two main sections, namely vegetative propagation by rooting cuttings or branches, and vegetative propagation by grafting. The important difference between these two types of propagation is the environment under which the propagules are placed. In rooting cuttings, the plant part is placed in sand, soil, peat-moss, water or some other type of medium and induced to form its own roots. In grafting, the plant part is placed on another plant part and made to unite with and grow upon this plant or part of a plant. Results of the grafting studies have been reported, and this paper deals with propagation by rooting.

The greenhouse experiments were conducted in the greenhouse of the Olustee Experimental Forest, with the exception of one study which was carried out in a greenhouse of the University of Florida at Gainesville. Field studies were carried out in the Olustee Experimental Forest and in the Osceola National Forest.

ROOTING OF SLASH PINES

Asexual propagation by the rooting of cuttings is the method used by horticulturists to propagate most of their ornamental plants. Although this technique has been practiced for several thousand years, it is only recently that extensive research has been conducted to try to correlate anatomical, physiological, and environmental factors with the rooting response of cuttings. Although a great deal of information has been accumulated on rooting experiments with horticultural plants, little work was done in the rooting of forest trees until 1935 when forest genetics became of interest.

Because cuttings or branches are genetically identical with the parent plant, this type of propagation permits direct multiplication of genetically superior trees and also allows the estimation of the genotype for such characteristics as form, growth rate, disease and insect resistance, gum yield, wood structure, and other similar characteristics.

Cuttings or branches may be classified according to the stage of development, or according to the plant part used. Past results with cuttings from older slash pines have shown that the distal points of branches during their dormant stage are best suited for propagation by cuttings. Studies have shown that rooting of slash pine cuttings from mature trees is physiologically possible. However, the percentage of rooted propagules is small, and slash pine can be considered as a species which regenerates roots with great difficulty. Cuttings from 1- to 2-year-old slash pines root easily. This is of little value to forest tree improvement programs, where emphasis is placed on the desirable characteristics of mature trees. Therefore, methods have to be developed which allow the multiplication of mature trees by rooting of cuttings or branches.

Events associated with the generation of roots from cuttings are complex and are not well understood. Anatomical characteristics of cells along the wound determine their meristematic abilities, and the physiological factors influence the organization and differentiation of the callus tissue which is formed. These internal factors are controlled by the interaction of genetic, nutritional, and developmental factors which are influenced by environmental conditions.

One of the major problems in rooting cuttings from conifers is to keep unrooted cuttings alive. The importance of stored carbohydrates, nutrients, and growth regulators to the formation of roots are factors well known to plant propagators and plant physiologists. By chemical treatment, various amounts of these substances can be supplied. If the relative amounts of these necessary materials can be augmented in cuttings without damaging the tissue or upsetting the metabolic balance, a favorable response should be obtained when they are placed in a suitable rooting environment. A good rooting environment also presents a propitious environment for pathogens; and the wound of the cuttings facilitates access for fungi. Therefore, the cuttings have to be protected from microorganisms. Either the rapid development of a protective pellicle or the use of an effective fungicide should help to minimize fungal infection.

The rooting experiments were designed to determine some of the limiting factors which control the rooting of slash pine cuttings from older trees. The possibility of inducing roots on the branches while they are still attached to the tree, was considered also. Various chemical and physical treatments, different environmental conditions, and effect of season were investigated. Results for each experiment are reported separately with a discussion on findings. The experimental findings of the various studies are brought together in a concluding general discussion and summary.

Review of Literature on Vegetative Propagation by Rooting

Root formation in cuttings from forest trees is varied. Some species regenerate roots quite readily and their vegetative propagation does not present a serious problem. However, cuttings from some species or even individuals within a species or variety are refractory to rooting. They do not form adventitious roots after they have been placed in a favorable rooting environment. The results of past experiments have shown that the internal and external factors which contribute to the rooting vary from season to season and from species to species. A review of some of these factors will help to a clearer understanding of this problem.

Effect of Age of Parent Tree

Results of the various experiments are in agreement with regard to the effect of age of tree on the rooting ability of the cuttings (Knight, 1932; Thimann and Delisle, 1939; Deuber, 1940). These investigations brought out the fact that the tendency to form roots is controlled by the age of the tree from which the cuttings were collected. Deuber (1940) noted a rather definite transition from a relatively high rooting response in cuttings from 4-year-old white pine trees to a moderate rooting response when the cuttings were collected from 5-year-old trees.

More than 90 percent of slash pine cuttings from young trees rooted in the first trials (Mitchell, 1942). Cuttings collected from older trees rooted poorly and with much difficulty (Schopmeyer, 1943; Dorman, 1947). Downs (1949) made a study to determine at what age the rooting capacity falls off in slash pine cuttings. He found that rooting and survival increased as the age of the tree from which they had been collected decreased. Downs considered that the dividing line between extensive rooting and poor rooting probably lies between 2-year-old trees and 3-year-old trees.

Type of Cutting Material

The part of the tree from which cuttings are collected has a marked influence on their subsequent rooting. However, this effect is not without variation and appears to change with the different species. In Quercus and Acer, the bases of young plants rooted better than the apices, and in Pinus and Picea the lateral shoots rooted more readily than the terminal shoots (Thimann and Delisle, 1939). Farrar (1947) noted that spruce cuttings from the lower part of the tree root best, but the longer cuttings develop into more desirable plants.

Small white pine cuttings collected from the lateral twigs survived better and gave a better rooting response than the larger cuttings taken from the terminal shoots (Deuber, 1940). Snow (1940) reported that white pine cuttings which had been collected from the side shoots of the lateral branches in the lower part of the tree rooted best. Long cuttings of Norway spruce were superior to short cuttings; a small heel of the previous year's wood inhibited rooting (Deuber and Farrar, 1940). In contrast to these findings, Grace and Farrar (1940), reported that short Norway spruce cuttings rooted in greater numbers than long ones.

Allsop (1950) working with Pinus radiata, suggested that the sunny side of the crown appears to be the best part from which to collect the cuttings. Removing the needles of white pine cuttings to reduce transpiration does not appear to be beneficial. Any type of needle removal with white pine cuttings resulted in excessive mortality (Snow, 1941b). Runquist and Stefansson (1951) in summarizing their rooting results with spruce and pine cuttings noted that the lateral shoots root better than the terminal ones. Slightly lignified cuttings rooted better than either very soft or very woody ones.

In earlier studies at Lake City, the bases of slash pine cuttings were prepared in a number of ways. They were sliced with a sharp knife, broken by hand, pulled from the tree (heels), the foliage sprayed with Dowax, and the needles stripped from the base (Schopmeyer, 1943; Dorman, 1947; Downs, 1949). None of these treatments gave results better than those obtained with cuttings severed with an anvil-type clipper.

Season of Collection

In the collection of cuttings, the time of year is an important factor and in many instances the success or failure of the work depends on this factor. Snow (1938) pointed out that, when collecting aspen cuttings, the season is of great importance. In a later study Snow (1939a) demonstrated that sugar maple cuttings obtained about the middle of June rooted satisfactorily, whereas cuttings taken after the middle of July did not root to any appreciable extent, irrespective of chemical treatment. The study by Deuber and Farrar (1940) brought out the importance of the effect of season when dormant Norway spruce cuttings were collected. The average rooting increased 255 percent from October to December, whereas the rooting capacity of the cuttings decreased in January. Thimann and Delisle (1939) reported similar results. Their rooting study with conifers showed a much higher rooting response in the winter months than during the summer.

During the first experiments with slash pine cuttings, which were conducted in outdoor propagation beds, the cuttings collected during the winter season did not survive as well as those which were collected during the summer (Mitchell, 1942). In later studies, Schopmeyer (1943) was able to induce roots in cuttings collected during October by placing them in a medium which was supplied with bottom heat. Bottom heat is important when cuttings are rooted during the winter months. The results of Dorman's study (1947) indicated that October and early November are the best periods to collect slash pine cuttings for rooting in the greenhouse. During the summer the experimental work is handicapped by the lack of temperature control.

Variation Between Trees

Rooting ability not only varies from species to species, but there is also a pronounced variation among individuals within a species. Snow (1939b; 1941c) reported that red maple clones responded differently to indolebutyric acid treatment. He concluded that this differential rooting ability was either conditioned by an inherent difference in natural rooting ability, or by an inherent difference in response to the auxin treatments. Deuber (1942) also reported some evidence of clonal variation in the rooting ability among individual white pine trees.

In dioecious species, the sex of the tree influences the rooting of cuttings. Snow (1942) reported that red maple cuttings from male trees rooted better, on the average, than those from female trees but that there were both high- and low-rooting clones for both sexes. The great variation in rooting response within a species might be of a general enough nature to necessitate the development of specific methods for the selected individuals (Snow and Duffield, 1940).

Duffield and Liddicoet (1949) used the rooting method as a guide to select superior individuals in a variable hybrid population. They found that wide differences occurred in rooting ability among members of the population under study.

Rooting experiments, with cuttings from selected slash pines of known gum-yielding capacity, revealed the existence of wide variations in rooting between trees (Dorman, 1947; Downs, 1949). It appears that some trees are evidently easy to propagate by rooted cuttings.

Chemical Treatment

About the year 1880, Sachs, a German botanist, postulated the presence of certain substances in plants which regulate the development of the specific plant parts. He suspected a certain "root-forming" chemical to be present which acts upon the underground structures of the plant (Hanley, 1939). There was little support for Sachs' theory until a chemical which had a regulating effect on certain plant parts could be extracted from the plant. Sachs' ideas were subjected to much criticism until Went (1929) reported that a substance extracted from plant tissues produced a marked stimulus in the rooting of cuttings. Since the time Went's work was published, many investigators have become interested in this phase of plant physiology. As a result of this interest the scientific literature on the effect of natural and synthetic rooting substances has become voluminous. In 1939, Pearse (1939) made an extensive review on the practical application of synthetic growth substances. He indicated that treatments with the various substances have not solved all the problems in plant propagation. Avery, et al. (1947) brought out the fact that the greatest contribution of plant hormones to vegetative propagation is earlier root formation, and in some plants a better root system. However, not all plants are affected in this way. In some species the rooting ability was not markedly improved by treatment with hormones, and these investigators stated that "thus far hormones are of no advantage whatsoever in rooting cuttings of plants that are never known to root without them."

The most common methods of treating cuttings for commercial purposes are soaking of the bases of the cuttings in an aqueous solution of growth regulators, spraying the foliage, or dipping the bases into a fine talcum powder in which growth substances have been mixed (Hitchcock and Zimmerman, 1939; Mitchell and Marth, 1947). Another method of applying root-promoting substances, although not widely used, consists of smearing a mixture of the substance with lanolin over the bases of cuttings (Maxon et al, 1940).

Hormone-treated Pinus radiata cuttings struck roots a week or two earlier than the controls and their root systems were larger and better balanced (Jacobs, 1939).

However, Allsop (1950) did not find a significant difference in the effect of "Rootone" on the rooting of Pinus radiata cuttings. Chemical pre-treatment of the base of Norway spruce cuttings with plain tap water or with indolebutyric acid, inhibited root formation. The best results were obtained by planting freshly collected cuttings directly in a sand medium (Deuber and Farrar, 1940). Eastern hemlock cuttings, when collected during the fall, are good examples of a plant adequately supplied with all the necessary factors for rooting except auxin. Cuttings taken from old trees rooted exceedingly well if they were treated with auxin but not at all in the absence of auxin (Thimann and Delisle, 1939).

Hitchcock and Zimmerman (1939) tested the effect of indolebutyric acid, naphthaleneacetic acid and indoleacetic acid on cuttings from some 70 species. Indolebutyric acid treatments, regardless of method of application, proved to be the most effective. Griffith (1940) tested cuttings of Douglas-fir and Sitka spruce with the same chemicals. He reported best response with indolebutyric treatment. His results seemed to indicate that the concentrations which have optimum effect varied with the time of year the cuttings were taken. Kirkpatrick (1940) found indolebutyric acid beneficial in his trials with a large number of evergreens, but cuttings of the genera of Cedrus and Pinus did not respond to the treatment.

The response to chemical treatment is greatly affected by the temperature of the medium. Temperatures below 60 degrees Fahrenheit decrease effectiveness of growth substances (Kirkpatrick, 1940).

Cuttings collected from the younger trees respond to root-inducing chemicals more positively than those from older trees. The treatment of hemlock cuttings with indolebutyric acid in talcum was more effective when cuttings were collected from very young trees than from trees 20 years old (Deuber, 1940). Root formation could also be stimulated in white pine cuttings when they were collected from young trees, but similar treatments of cuttings collected from older trees were effective only in a few cases (Deuber, 1942). Chemical treatment of slash pine cuttings from very young plants also was found to be beneficial (Mitchell, 1942).

Past results of the rooting experiments with cuttings from mature slash pine trees have not definitely established the beneficial effect of chemical treatments (Schopmeyer, 1943; Dorman, 1947; Downs, 1949). Results varied from year to year and with different trees. A total of 290 chemical, physical, and environmental treatments have been used in outdoor and greenhouse propagation experiments. None of the treatments or treatment combinations gave consistently better results; many times results in the following years contradicted conclusions of the earlier studies. Cuttings have rooted under more than 35 types of treatments. These conditions ranged from no treatment to the most complex chemical treatment with growth regulators, vitamins, nutrients, sugar, and fungicide.

Medium and Environment

Sterile sand is most widely used as a propagation medium because sand is cheap, easily obtainable, and retains moisture fairly well. Other materials, either in a mixture with sand or separately are often superior to sand. However, there is no standard mixture which gives best results with all species. Hitchcock (1928) reported from his study of different types of rooting media that the various species have specific requirements as to acidity and aeration. Grace, et al.(1940) obtained best results with a sand-peat mixture. They related the pronounced stimulation of new growth in a sand-peat mixture to a nutrient factor from the peat. Deuber (1940), however, found sand to be superior to either peat, or a mixture of sand and peat. The advantage of vermiculite as a propagating medium for rooting conifer cuttings was demonstrated by Matthews (1953).

Grace and Farrar (1940), working with Norway spruce cuttings found a change in effect of media as the season progressed. With cuttings collected during March, the addition of peat moss to the propagating medium had a significantly injurious effect, whereas in a similar experiment four months earlier a beneficial effect resulted from the mixture.

Builder's sand was used in most of the past experiments with slash pine cuttings. Sphagnum moss, shredded redwood bark, and mixtures of 50 percent and 75 percent of bark with sand have been used, but best results have been attained with sand alone (Dorman, 1947).

Root formation in many types of cuttings is hastened if the rooting medium at the base of the cutting is kept at a warmer temperature than the air which surrounds the top of the cutting (Price and Hurd, 1932). Temperature control of the medium is especially important when root-inducing hormones are used, as they appear to become inactivated at the lower temperatures (Kirkpatrick, 1939). After an initial cool period, these substances cannot be reactivated by raising the temperature.

Growth of Cuttings

When a number of plants are propagated vegetatively from one seedling or bud sport, they are known collectively as a clon or clone, and the individual plants of such a clone are known as ramets (Stout, 1929). In agriculture, many plants have been propagated vegetatively through centuries without a loss in vigor. Investigation of reported cases of supposed senescence in clones have proven that environmental or disease factors were the causal agents (Schreiner, 1937). From evidence Pawsey (1951) had gathered, he believed that deterioration in vigor would not likely ensue from the repeated vegetative propagation of Monterey pine. He observed that there was a striking uniformity within the clones of Monterey pine in such attributes as vigor, limb size, type of branching, nature of bark, and the size, shape and distribution of the cones.

Cuttings collected from the lateral branches of Picea retain a plagiotropic growth habit for some years after they have rooted (Thimann and Delisle, 1939; Farrar, 1947). This phenomenon is not evident in Pinus, and the rooted lateral branches seem to grow as straight as the terminals (Thimann and Delisle, 1939). Rooted white pines started from rooted cuttings showed very little evidence of plagiotropic growth, but the growth was slower and growth features were more erratic than in plants raised from seed. In addition, the root system did not produce a tap root but spread laterally instead (Farrar, 1947). Rooted slash pine cuttings show an orthotropic growth habit (Mergen, 1953a), but they have a tendency to develop a unilateral root system.

Experiment 1. Effect of Mode of Chemical Treatment, Treatment Under Vacuum, and Storage of Cuttings, on the Rooting of Slash Pine Cuttings

In regular nursery practice the bases of cuttings are treated under normal atmospheric pressure with the growth regulators, nutrients or sugar. So far, this type of treatment has not given any significant beneficial effect with slash pine cuttings. In healthy plants the root growth hormones travel from the buds downward to the root system, whereas mineral elements travel in the opposite direction. When cuttings are stored for a short period under warm and moist conditions, callus growth is stimulated. This growth helps to protect the cuttings against fungi. In this study, half the slash pine cuttings were stored for 2 weeks before they were treated. An attempt was made to stimulate root formation by treating the needles of the cuttings with the growth regulators and treating the bases under reduced pressure with nutrients. Several of the most promising root-forming substances were tested in a mixture with root growth factors, mineral elements, sugar, and a fungicide.

The movement of auxin in a vascular plant has certain characteristics which distinguish it from the translocation of the plant solutes. In undamaged plants, auxin moves only from the apical buds of the plants downward and this polar movement hinders the upward movement of auxins. This translocation of auxins is not entirely the result of a diffusion process but it is dependent upon expenditure of energy (Bonner and Galston, 1952). Oserkowsky (1942) was interested in auxin movement in perennial stems during the dormant period. He studied transport of auxin in pear and apple twigs during the resting period as well as during the active period. Native auxins moved almost entirely in a basipetal direction. When native auxin was applied externally by means of agar blocks, it was transported basipetally and no measurable transport could be detected in the opposite direction. However, the transportation of synthetic auxin-like substances in the resting twigs was both polar and apolar. He ascribed the apolar movement to a diffusion process through the lumina of dead cells and through cell walls, the direction of transport being determined by the concentration gradient.

Red maple cuttings, treated for 3 hours with the three growth-substances, indolebutyric, indoleacetic, and naphthaleneacetic acids at concentrations of 100, 200, and 400 ppm., showed a differential response in both percentage rooting and type of roots produced with the different chemicals (Snow, 1941a). Indolebutyric acid appeared to be the best of the growth substances tested, with indoleacetic acid decidedly inferior to either of the two other chemicals for red maple. Beneficial effects of these growth regulators have been reported by a large number of investigators and they are widely used in commercial plant propagation.

If roots are to be grown successfully in vitro they need traces of vitamin B_1 in the medium. Bonner (1937) considered vitamin B_1 to be a hormone-like substance regulating root growth. However, Tincker and Unwin (1939) reported that in their rooting experiments with plants responding to growth substances, the addition of aneurin (vitamin B_1) had only a small effect. The addition of aneurin increased the number of rooted cuttings in only half their experiments.

The auxins are of primary importance in the initiation of root primordia, and other growth factors are necessary for the growth and full development of these primordia. The substances necessary are not synthesized in the roots but are translocated downward from the leaves. The root growth factors known at present are thiamine, nicotinic acid, and pyridoxine. Roots of some plants will not grow unless pyridoxine is synthesized in the leaves and translocated to the roots, or is added to the growth medium (Bonner and Galston, 1952).

Adding mineral nutrients and sugar to the treating solution did not show any consistent effect on slash pine cuttings (Schopmeyer, 1943; Dorman, 1947; Downs, 1949). Summer cuttings showed a better survival, while the effect on fall cuttings was not as great and in some cases the treated cuttings did not survive as long as the controls. Grace and Thistle (1939), however, observed beneficial effects when they treated cuttings of Lonicera tartarica for a 24-hour period in a 0.1-percent nutrient solution. The use of a nutrient solution produced a significant stimulation.

The conventional method of treating cuttings with a root-promoting solution is to submerge the base of the cuttings into the solution under normal atmospheric conditions. In order to improve on the technique of rooting plant materials, Butterfield and McClintock (1939) treated their cuttings under a vacuum of 29 inches of mercury in a solution of growth-promoting substances. When they treated their cuttings for a period of 4 hours, subsequent growth of the plants was not inhibited. Easily rooted cuttings responded well to the vacuum treatment. Roots which developed after soaking the cuttings in a solution of indolebutyric acid were thin and short, but cuttings which had received the vacuum treatment had well-developed roots.

Stoutemeyer, et al. (1940) considered the success in chemical treatment of locust hardwood cuttings dependent upon the formation of callus on the basal ends of the cuttings before the chemical treatment. Cuttings which were well callused before treatment were not injured by the concentrations necessary to induce abundant rooting.

Schopmeyer (1943) obtained greater survival and rooting of slash pine cuttings when the cuttings, which were collected during October, were stored upright in wet sphagnum moss for 2 weeks at 85°F. before they were planted. The data from Dorman's experiment (Dorman, 1947), however, invariably indicated a decrease in survival for both summer and fall cuttings receiving a storage treatment. Duplication of environment from year to year, even in the same greenhouse, is extremely difficult, in fact practically impossible. This makes the isolation of one single treatment effect out of several complex treatments an almost impossible task.

Experimental Methods

Collection of cuttings.--On October 13, 1952, the 660 cuttings used for this experiment were collected from 10 slash pines 20-25 years old growing in an old-field stand on the Osceola National Forest. The trees had well-developed crowns and were in a vigorous growing condition. The results from previous rooting experiments indicated that October and early November were the most desirable periods for collecting slash pine cuttings. However, the environment in a greenhouse is confounded with season of collection.

The cuttings were collected from the distal points of the middle and upper part of the crown; large succulent cuttings from the topmost branches were not used. To avoid inherent rooting difficulties, the cuttings collected from the 10 trees were mixed before they were allocated at random to the various treatments.

Treatments

A. Chemical treatment.

1. Basal ends of cuttings were submerged in a solution (called Solution 1) containing 25 ppm. indolebutyric acid, 12 ppm. indoleacetic acid, 12 ppm. naphthaleneacetic acid, 0.4 percent nutrients,[2/] 5 ppm. thiamine, 1 ppm. nicotinic acid, 1 ppm. pyridoxine, 5 percent sucrose, and 20 ppm. sodium pentachlorophenate (fungicide).

2. Upper part of cuttings were submerged in a solution (called Solution 2) containing 25 ppm. indolebutyric acid, 12 ppm. indoleacetic acid, 12 ppm. naphthaleneacetic acid, 5 ppm. thiamine, 1 ppm. nicotinic acid, and 1 ppm. pyridoxine.

After this treatment, the cuttings were reinverted and placed with their bases in a solution (called Solution 3) containing 0.4 percent nutrients, 5 percent sucrose, and 20 ppm. sodium pentachlorophenate.

B. Vacuum treatment.

1. Treatment under atmospheric pressure, 30" Hg. The treatments under normal pressure conditions were carried out, using 60 cuttings at one time, in a pail with 2 liters of solution. About 1½ inches of the cuttings were submerged. The pails were placed in a shaded location in the laboratory during treatment. Using chemical treatment A1, the bases were submerged for a 24-hour period. With treatment A2, the needles were submerged for a 20-hour period in Solution 2, after which they were placed with their bases in Solution 3 for a 24-hour period.

2/ Commercially available soluble HYPONEX was used in all of these studies.

2. Treatment under one-half atmospheric pressure, 15" Hg. Treatment under vacuum was done in large desiccators. For the 15" Hg. treatment with Solution 1, the cuttings were brought to a pressure of 15" Hg. in a closed system containing Solution 1 in the well of the desiccator. They were suspended in bundles of 4 above the solution in the desiccator during evacuation of the air (fig. 1). After the pressure had reached 15" Hg. they were lowered with their bases into the solution and the pressure was allowed to return to normal (fig. 2). This cycle was repeated two more times. During this procedure, the air was evacuated from the intervascular spaces and thus the growth regulators and nutrients entered the cuttings. After the third cycle was completed, the cuttings were left in the solution for an additional 2-hour period.

Treatment in Solution 2 at 15" Hg. followed the same procedure as outlined in the previous paragraph. However, the upper parts of the cuttings were submerged to the same depth into the solution containing the growth regulators. After this treatment, the cuttings were placed under normal pressure conditions with their bases in Solution 3 containing the nutrients, sugar and the fungicide for a 24-hour period.

C. Storage treatment

1. Treatment immediately after collection.

2. Storage in sphagnum moss for a 2-week period prior to treatment. Cuttings receiving the storage treatment were placed in a wooden box containing a 10-inch layer of moist sphagnum moss. The tops of the cuttings were covered with a light layer of sphagnum moss which was kept moist at all times. This maintained a high humidity around the cuttings and also allowed good aeration around the bases. The temperature of this precallusing medium was kept at 85°F. by means of a thermostatically controlled lead-sheathed heating cable.

For analysis of the data, treatment with Solution 1 at 1 atm. without storage treatment was the standard for the comparison. In addition to the 8 treatments outlined above, untreated checks with and without storage were planted for general comparisons.

Design of the Experiment in Greenhouse

The experiment was designed for statistical analysis, using a 2 x 2 x 2 factorial design. This type of design allows for the simultaneous comparison of the effects of the direct factors and their interrelations. The cuttings were planted in two randomized blocks with 30 individuals per treatment per block. They were placed in the two north propagation benches in the Olustee Experimental Forest greenhouse. Clean sand was used as a rooting medium and the cuttings were spaced at 4 x 5 inches (fig. 3). The temperature in the sand beds was kept between 80° and 85°F., using thermostatically controlled heating cables.

No fixed watering schedule was used during the 13-week duration of the experiment. An automatic overhead spray system covered the cuttings with a fine spray for 1 minute out of every 10-minute cycle during the daylight hours. This schedule, however, was very flexible and whenever undue drying of the cuttings was noticed it was changed to provide more water.

The glass roof of the greenhouse was cleaned of any residual whitewash to let the maximum amount of light reach the cuttings. They obtained full sunlight from 10 a.m. until 4 p. m.

Figure 1.--Chemical treatment of cuttings under reduced air pressure. Step 1. The bundle of cuttings are suspended above the solution while the air is evacuated from the desiccators.

Figure 2.--Chemical treatment of cuttings under reduced air pressure. Step 2. After the air in the desiccators was brought to a pressure of 15" Hg., the cuttings were lowered into the solution, and the pressure was allowed to return to normal.

Figure 3.--General view of cuttings in propagation beds in the greenhouse. The cuttings were spaced at 4 x 5 inches and planted in sterile sand. Slash pine cuttings, being large, require a great deal more space than most other conifer cuttings.

Collection of Data

Survival counts of the cuttings were taken at 2-week intervals beginning 4 weeks after the day of planting. A cutting was considered dead if a large proportion of the needles had turned brown, or when most of the needles, although still green, could be stripped off with a gentle pull. The final count of rooted cuttings was made on January 13, 1953, when the experiment was discontinued and the cuttings were lifted. The base of each cutting was washed clean to observe its condition. Cuttings listed as alive were dissected to check their condition.

Results on Survival and Rooting

The survival of the cuttings is graphically represented in figure 4, where survival percentages are plotted against time after collection. Data on the number of cuttings which survived 12 weeks after collection and those which had produced roots are summarized and expressed as percentages in table 7 of the appendix. An analysis of variance was made of the survival percentages using an angular transformation. It is quite evident that there was a decided difference in survival under the various treatments. The over-all rooting response was very poor and the meager data on root formation were not suited to an analysis-of-variance procedure. Many cuttings had formed callus on their bases without developing roots and in many instances the callus had turned brown and rotted away.

Survival of the cuttings reflected the effect of treatment and it was felt that the data on survival were of value in indicating the physiological effects of the various treatments. Table 1 gives results of the analysis of variance on survival of the cuttings in the main part of the factorial experiment, while analysis results of the comparisons with the untreated checks are given in table 2. The treatment effects and the interaction between treatments will be discussed under their appropriate headings.

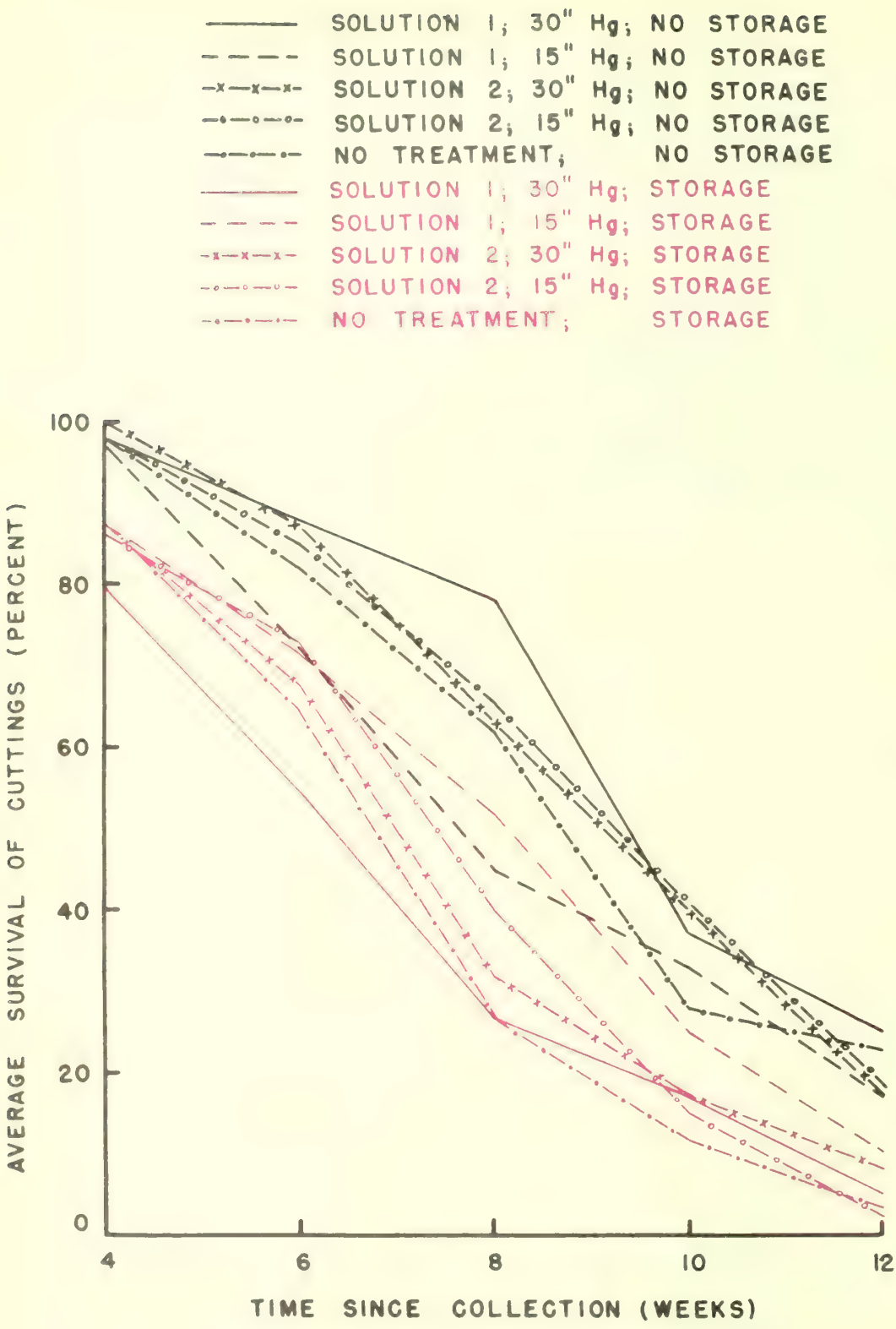


Figure 4.--Survival of slash pine cuttings.

Table 1.--Analysis of variance of cuttings alive after a 12-week period. All data were transformed by the angular transformation (Bliss, 1937)

Source of variation	Degrees of freedom	Mean square
Block	1	63.52
Treatment	7	139.62
Solution	1	78.68
Pressure	1	12.18
Storage	1	780.64**
Solution x pressure	1	4.77
Solution x storage	1	14.96
Pressure x storage	1	1.50
Solution x pressure x storage	1	84.64
Error	7	61.34

** Exceeds mean square error, 1-percent level of significance.

Table 2.--Analysis of variance of cuttings (checks) alive after a 12-week period. Untreated checks with and without storage treatment were compared with cuttings receiving treatment with Solution 1 at 30" Hg. All data were transformed by the angular transformation (Bliss, 1937)

Source of variation	Degrees of freedom	Mean square
Block	1	20.257
Treatment	3	257.710
Storage	1	744.401*
Chemical treatment	1	20.384
Storage x chemical treatment	1	8.344
Error	3	38.462

* Exceeds mean square error, 5-percent level of significance.

Effect of Technique of Chemical Treatment

Immersion of the needles in the growth regulator solution with subsequent basal treatment with nutrients, sugar, and a fungicide did not affect the ability of a cutting to survive or produce roots. They did not differ significantly from the control in respect to survival after the 12-week period. The interaction with other treatments was not significant.

Effect of Vacuum Treatment

The data on survival after vacuum treatment did not show any significant treatment effects and the interaction between other treatments was not significant. The vacuum treatment apparently did not damage the cuttings, as the rate of mortality was the same as that of the cuttings not treated under vacuum.

Effect of Storage Treatment

There was a highly significant difference between the survival of the cuttings planted immediately after collection and those which were stored in sphagnum moss for a 2-week period. The effect of the preplanting storage was depressing. Without storage 19.2 percent of the cuttings had survived, and after storage only 6.3 percent; the values given are the averages for both pressure treatments and method of treatment. However, the interaction between the other treatments was not significant. Figure 4 clearly illustrates the depressing effect of the storage treatment.

Comparison of the Untreated Checks

Rooting of the untreated cuttings was of the same order as that of the treated ones. The experiment failed to detect any significant effect of the growth regulators, mineral elements, sugar and a fungicide on survival or rooting of the cuttings. It is apparent that the storage of the untreated and treated cuttings reduced the survival. The difference was significant at the 5-percent level.

Discussion and Conclusions

None of the treatments tested had any significant beneficial effect on the rooting of cuttings. Survival of the cuttings was quite good and compared favorably with that obtained on the average in previous rooting experiments with slash pine. The two propagation benches used for this experiment received a great amount of solar radiation and this resulted in heating and drying of the needles during the "off" period of the sprinkler system, which probably accounts for the low number of rooted cuttings obtained. Downs (1949) reported a decrease in survival with increasing amounts of sunlight during summer rooting experiments with slash pine cuttings in the greenhouse. Results of the experiments during the winter months, however, contradicted his earlier findings. The glass of the greenhouse was painted white for his experiments and consequently only a small percentage of the rays reached the needles of the cuttings.

In his rooting experiments with five conifers and three broadleaved species, Heitmuller (1952) also found that direct sunlight hindered rooting, but that there was no difference betwen cuttings rooted in darkness and in indirect sunlight. Conifer needles can assimilate under various light intensities and do not require direct solar rays for photosynthesis. Vekhow (1934) recommended diffused light of sufficiently high intensity for optimum rooting conditions. He considered the shading of beds which are supplied with bottom heat as extremely important. When white pine cuttings were watered from above while strong sunlight was upon them, they were injured as a result of burning of the foliage (Doran, 1946).

The chemical composition of the treating solution was a slight modification of that which was first used by Mitchell, et al. (1942) in their attempts to develop satisfactory rooting methods. The chemical treatments, however, had no positive effect on survival or rooting. The needle color of the cuttings treated under vacuum changed to a pronounced dark green within a day after treatment. This was probably the result of excess uptake of mineral elements. The color returned to normal within one week after treatment.

It is noteworthy that chemical treatment had no positive effect on the rooting of cuttings; the effect of rooting medium, high air temperature and fungus attack probably overshadowed any possible beneficial effect of the chemical treatment. When information on a more dependable rooting environment has been obtained, critical tests can be made to isolate the effect of certain chemical treatments.

Most of the cuttings stored in sphagnum moss had a well-developed protective pellicle over the wounded surface and on better than 50 percent of the cuttings callus formation had started. None of the wounds, however, was completely covered by callus. The rapid callus formation was probably the result of good aeration around the bases, along with the high temperature of the sphagnum moss. This environment was also favorable for fungus growth, and hyphae were evident on the wounded surface on a large number of the stored cuttings. The pronounced decrease in survival as a result of this storage can probably be attributed to fungal infection. The wounded surface of the cuttings became infected and the parenchymatous tissue around the base of the cuttings was destroyed before the callus covered the wound. At the start, the fungus attack probably proceeded parallel with the development of the callus, but later on spread all over the tissues of the lower portion of the cutting and hindered the movement of sap between the newly formed callus and the base of the cutting. Snow (1938) also reported the rotting of the bases of aspen cuttings after they had formed abundant callus. Deuber (1940) followed the method outlined by Stoutemeyer, et al. (1940) for precallusing cuttings. These conditions caused white pine cuttings to callus promptly, but rotting of the stem bases was rapid and severe. This fungus infection could be overcome by sterilizing the sphagnum moss. However, if a favorable, well aerated, sterile rooting medium is used, it is hard to visualize any possible beneficial effect to be obtained by this storage treatment.

The results of this experiment point strongly toward the importance of environment, and further studies should be directed toward improving the present conditions under which cuttings are rooted.

Experiment 2. Effect of Chemical Treatment and Rooting Media on the Rooting of Slash Pine Cuttings

When placed in a favorable rooting environment, the life of the cutting largely depends on the nutrients and carbohydrates which were present in the cuttings before they were severed from the tree. Supplementing these stored products by supplying nutrients and carbohydrates through the foliage while the cuttings are in the propagation bench should result in a higher survival of these cuttings. Good aeration of the medium favors root growth in most plants. In this study, treated cuttings were planted in two types of media. They were supplied with nutrients and carbohydrates throughout the rooting period. The treating solution used was similar to Solution 1 in Experiment 1, except that traumatic acid was substituted for the three root-forming substance.

Review of Literature

If cuttings can be kept fresh and green for a long enough period, they will strike roots sooner or later. Many cuttings possibly die because of nutritional deficiencies. Albino corn plants usually die within a short time, since they are unable to synthesize carbohydrates (Srb and Owen, 1952). But if such plants are nurished by placing their leaves in a sugar solution, they may survive for several months and develop as many leaves as normal green corn plants. However, if the roots of the albino plants are placed in a similar sugar solution, the plants do not develop as well. Direct nourishment through the needles is more effective than feeding through the roots. Experiments reported by Fisher, et al. (1948) indicated the possible beneficial effect on the setting of apples by spray applications of urea in water solution. Nutritional sprays take advantage of the ability of the plants to absorb the elements through their leaves, and spray applications of deficient elements have become a common practice in Florida's citrus industry (Camp, 1953). Stoate (1950) was able to correct nutritional disorders in Monterey pine planted in New Zealand, by spraying a solution of commercial zinc sulphate on the needles.

The control of the environment during rooting is most important to keep the cuttings alive. Sand is probably the most widely used rooting medium but investigations show that it is not always the best material for rooting cuttings (Grace and Farrar, 1940). A variety of materials, either in mixture with sand or alone, is sometimes greatly superior to sand alone. Vermiculite, manufactured by exploding mica under intense heat, is widely used as a medium for rooting cuttings. It is chemically inert, pleasant to handle, and gives excellent results for rooting various horticultural plants (Watkins, 1952). In his rooting experiments with redwood cuttings, Matthews (1953) noted that rooting was far superior if the cuttings were planted in peat, vermiculite, and mixtures of peat and vermiculite. Pure quartz sand gave the lowest rooting response out of 12 different types of media tested.

Experimental Procedure

Collection of the cuttings.--The cuttings for this experiment were collected on October 13, 1952, along with those for Experiment 1. The conditions of collection as indicated on page 12 were used.

Treatments

A. Chemical treatment

1. The bases of the cuttings were treated for a 24-hour period in a solution (called Solution 4) containing 25 ppm. traumatic acid, 5 ppm. thiamine, 1 ppm. nicotinic acid, 1 ppm. pyridoxine, 0.4 percent nutrients, 5 percent sucrose, and 20 ppm. pentachlorophenate (fungicide). The cuttings were placed in pails containing 2 liters of the solution, and about $1\frac{1}{2}$ inches of the bases of the cuttings were submerged.

After the basal pretreatment, the cuttings were planted in propagation benches. Tips of several of the needle fascicles were placed in a glass vial containing a solution of 5 percent sugar and 0.1 percent nutrients (Hyponex). The needles were kept in place by cotton stoppers (fig. 5). Special wooden racks held the vials in position. The vials were exchanged every 3 weeks with new ones containing a fresh supply of solution to minimize adverse effects of fermentation and fungus infection.

2. Cuttings receiving treatment A2 had the same basal treatment as under A1. After the cuttings were planted in the benches, they were sprayed twice a week with a solution containing 10 percent sugar and 0.2 percent nutrients (Hyponex). Spraying was done during the early morning before the sprinkler system started to operate. Polyethylene spray bottles were used, and each cutting was covered with a fine spray for about a 3-second period. The solution and spray bottles were stored in a refrigerator to prevent fermentation of the solution.

3. Cuttings planted without chemical treatment (control).

B. Rooting media

1. Clean fine sand.

2. Equal mixture of sand and vermiculite by volume.

Design of Experiment in Greenhouse

The experiment was designed for a 3 x 2 factorial analysis and the cuttings were planted in two randomized split plots with 30 cuttings in each of the 12 individual plots. The location of the treatments was assigned by the use of random numbers.

Figure 5.--Three cuttings receiving treatment A1. The tips of several of the lower needle fascicles of each cutting were submerged in a sugar and mineral element solution. The cotton stoppers held the needles in place in the vials.

The cuttings were spaced at 4 x 5 inches in the rooting media, which was maintained at a temperature of about 80 to 85°F. by the use of thermostatically controlled heating cables. The medium was not firmed after the cuttings were inserted.

The sprinkling system was kept at a flexible schedule. During most of the experiment the overhead nozzles sprayed a fine mist on the cuttings during the daylight hours for 1 minute out of every 10-minute cycle. This schedule was changed whenever there was an indication of drying of the cuttings in order to provide more water to the beds. The beds were shaded all day and did not receive direct sunlight during the experiment.

Collection of the Data

Survival counts of the cuttings were taken every 2 weeks, starting 4 weeks after collection. The cuttings were lifted carefully and each base was washed clean in a pail of water for examination. Cuttings recorded as being alive were dissected to study the condition of the stem.

Results

The data on survival are represented graphically in figure 6, where average survival percentages are plotted against time elapsed since collection. Differential effects of the chemical treatments and media on the rooting response are given in table 8 of the appendix. The results of the analysis of variance on rooting percentages are reproduced in table 3.

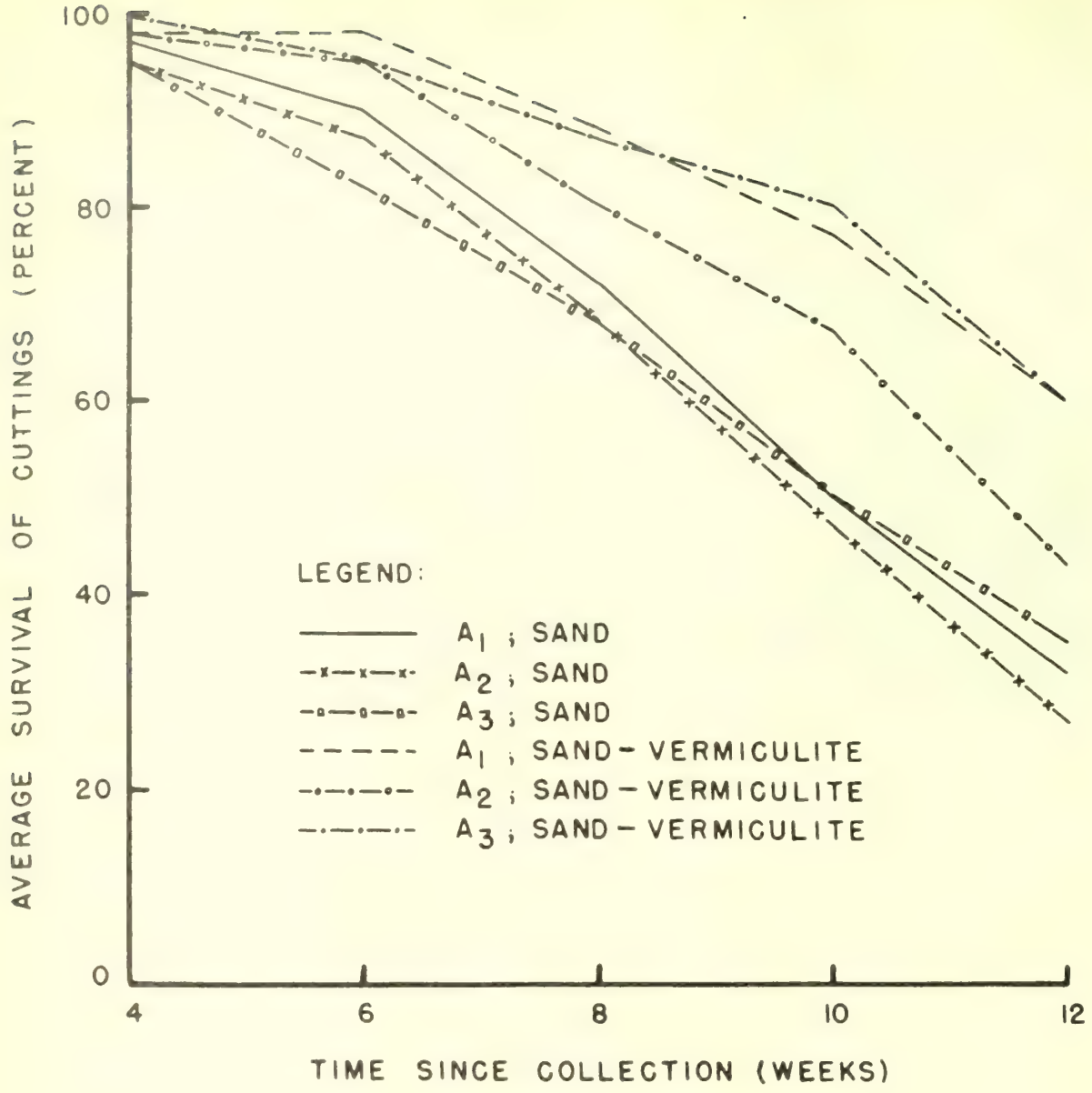


Figure 6.--Survival of slash pine cuttings.

The sand-vermiculite mixture gave a significantly better rooting response. The best rooting, 36.6 percent, was obtained by planting the cuttings without any chemical pretreatment in propagation benches filled with sand-vermiculite mixture.

The chemical treatments tested failed to improve rooting of the slash pine cuttings. Application of nutrients by spraying cuttings twice a week reduced survival significantly in both the sand and sand-vermiculite beds.

At the time the cuttings were lifted, most of the surviving cuttings had formed a satisfactory callus cover over the wound. Root formation, however, was quite varied. Some cuttings had formed several roots with satisfactory secondary branching. The largest root was 4 inches in length, while on some cuttings root development had just begun and was only a few mm. in length (fig. 7). No relationship between root length and either position in propagation bed, treatment, medium, or type of cutting

was apparent. No rooting was observed in the absence of callus. Most roots emerged toward the edge of the callus collar and continued growth in a downward direction. In several instances the roots grew horizontally at right angles to the stem of the cutting.

A large percentage of the cuttings which rooted had well-formed male catkins. The presence of both male and female flowers on slash pine cuttings appear to be of little or no consequence.

Table 3.--Analysis of variance of cuttings which rooted after a 14-week period. All data were transformed by the angular transformation (Bliss, 1937)

Source of variation	Degrees of freedom	Mean square
Block	1	0.827
Medium	1	312.834*
Error (a)	1	0.827
Treatment	2	150.289*
Treatment x medium	2	20.916
Error (b)	4	18.679

* Exceeds mean square error, 5-percent level of significance.

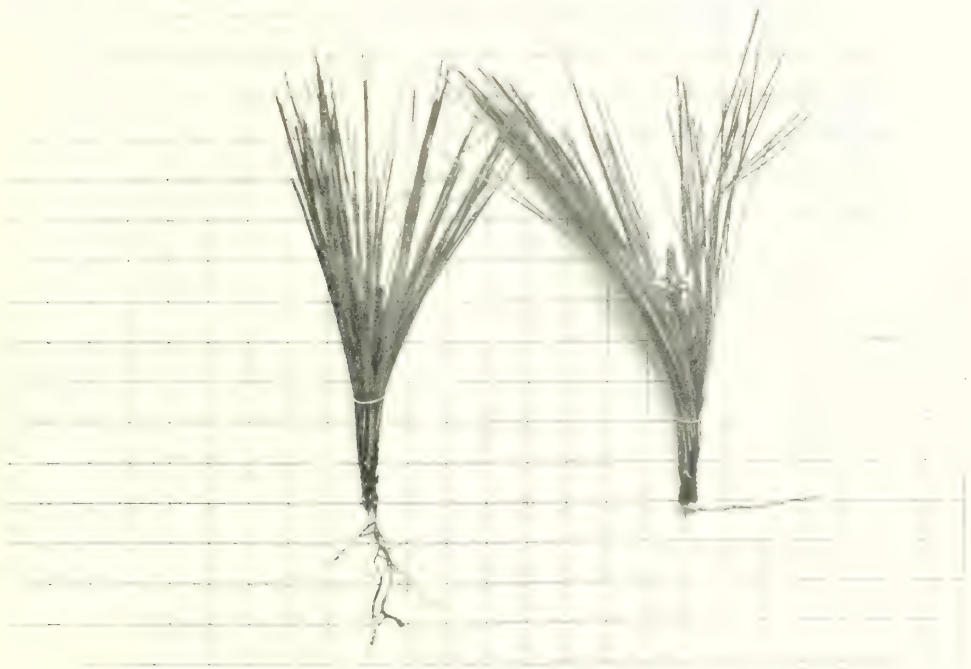


Figure 7.--Rooted slash pine cuttings illustrating characteristic types of rooting. The roots at left developed in a downward direction and were branched. The root on the cutting at the right grew at right angles to the cutting, making a very unsatisfactory type of root system. Root initials in both cuttings formed in the callus rim. Note staminate flowers on the cuttings at right.

Discussion and Conclusions

The outstanding feature of this experiment was the beneficial effect of vermiculite in the rooting medium. Beneficial effects from vermiculite mixtures as rooting media have been recognized previously (O'Rourke and Maxon, 1948; Pridham, 1948; Matthews, 1953), but this is the first time that vermiculite was tested with slash pine cuttings. The high average level of rooting attained in this experiment can be largely attributed to the sand-vermiculite propagation medium, along with the shading of the beds. Since results with untreated cuttings surpassed those with chemical treatment, and rooting in the sand-vermiculite mixture was better than in pure sand, it can be concluded that the physical nature of the medium is of greater importance than chemical treatment when propagating under suboptimum conditions. Aeration and moisture retention are among the characteristics to look for in a good rooting medium, and various chemical treatments can express their relative effects on cuttings only if they are growing in a favorable environment.

Foliage spray with the nutrient solution had a significant depressing effect. Examination of bases of the cuttings and needle fascicles showed heavy fungus infections. The supply of nutrients favored a large population of micro-organisms which destroyed the parenchymatous tissues of the cuttings.

The presence of male catkin primordia in Monterey pine hindered the rooting of cuttings according to Jacobs (1939). He recommended that shoots which show evidence of male catkins be rejected. The results of previous experiments with slash pine (Dorman, 1947) as well as those of this study did not show any relationship between sex and flower development of a cutting and its subsequent rooting. These results appear to contradict Jacobs' findings. Both male and female flowers developed on the rooted cuttings while they were in the propagation beds. Duffield and Liddicoet (1949) reported that cuttings of the hybrid P. attenuata x radiata bearing male catkins rooted readily.

Survival and rooting of the untreated cuttings in the two unshaded beds used in this experiment was significantly greater than in the two propagation benches used in Experiment 1. Cuttings used in both experiments were collected from the same trees, the sand was maintained at the same temperature, and the spray schedules were very similar. The only difference in environment was the direct insolation of the benches used in Experiment 1. Therefore, it can be concluded that direct insolation has a detrimental effect on the survival of slash pine cuttings planted in the greenhouse during the fall and winter months.

Experiment 3. Applicability of Closed Propagation Frame and Chemical Treatment to the Rooting of Slash Pine Cuttings

This experiment was designed to obtain information on the applicability of closed propagating frames to the rooting of slash pine cuttings collected during the month of October. Cuttings of the same species behave differently when they are subjected to slightly different environments during the rooting period.

Experimental Methods

A closed propagating frame was made available for this study by the Horticulture Department of the University of Florida, in Gainesville. The raised propagating frame was located in a large greenhouse and the sash over the case was fitted with glass. The minimum temperature in the greenhouse was thermostatically controlled and bottom heat was supplied to the beds only by the pipes of the heating system. The rooting medium in the frames was fine builder's sand, and high humidity was maintained in the greenhouse at all times by watering the walks at various intervals during the day.

The closed propagation frames in this greenhouse are used for teaching and demonstration purposes. They provide a favorable environment for rooting the cuttings of most horticultural plants.

Four treatments were used in this experiment and the cuttings were planted in a randomized block design. Two blocks with 25 cuttings for each treatment per block were used. The following chemical treatments were selected for the study:

1. Basal part of cuttings treated for a 24-hour period in a solution containing the following ingredients: 25 ppm. indolebutyric acid, 12 ppm. indoleacetic acid, 12 ppm. naphthaleneacetic acid, 0.4 percent complete nutrient solution, 5 ppm. thiamine, 1 ppm. nicotinic acid, 1 ppm. pyridoxine, 5 percent sucrose, and 20 ppm. sodium pentachlorophenate (fungicide).

2. Treatment for a 24-hour period in a solution containing the following ingredients: 25 ppm. traumatic acid, 5 ppm. thiamine, 1 ppm. nicotinic acid, 1 ppm. pyridoxine, 0.4 percent complete nutrient solution, 5 percent sucrose, 20 ppm. sodium pentachlorophenate.

3. Cuttings stored for a 2-week period in sphagnum moss maintained at 85°F. After the storage treatment the cuttings were treated as under 1.

4. Untreated cuttings (Control).

The cuttings for this study were collected on October 15, 1952, using the same criteria as for the previous studies. Immediately after the cuttings were planted in the frame, the rooting medium was soaked and the sash closed down to maintain a high relative humidity around the cuttings. The frame was covered with several layers of paper to exclude most of the light and decrease transpiration of the cuttings. The cover was lifted each day to permit sprinkling the needles with a mist-like water spray. The paper shades were removed completely after a 2-week period and the frame was aerated for short periods each day. Ventilation was increased whenever saprophytic fungi became evident. The sash was left open during the latter part of the experiment (fig. 8).

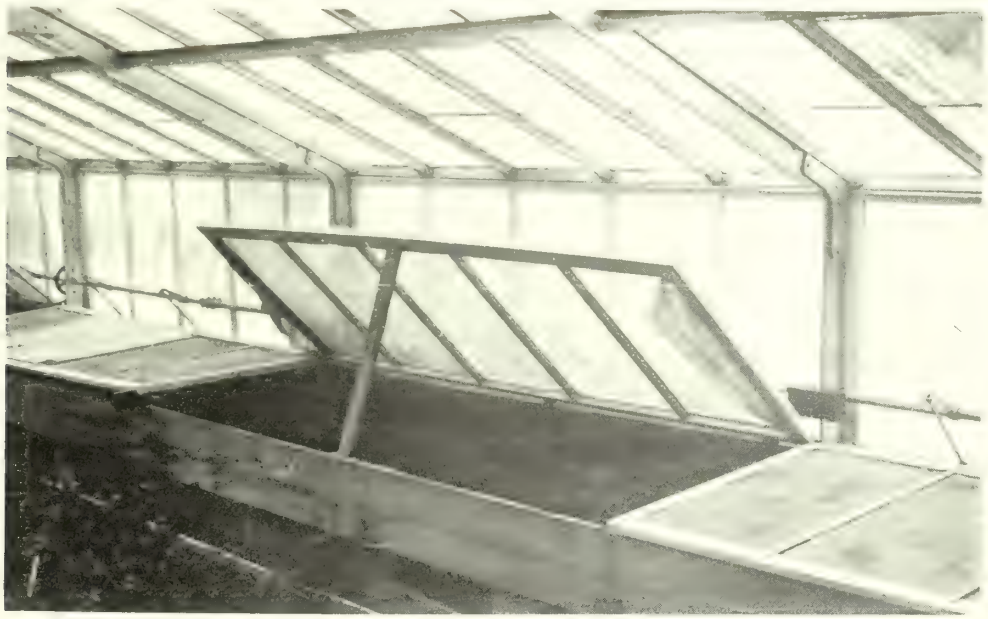


Figure 8.--Propagation frame in the greenhouse of the Horticulture Department of the University of Florida, Gainesville. The cover was closed during the early part of the experiment, but the high incidence of saprophytic fungi made it desirable to keep the cover open and allow for more ventilation. This type of environment was not satisfactory for rooting slash pine cuttings.

Results and Discussion

Survival data taken at various periods during the experiment are given in table 9 of the appendix. Survival of cuttings was very low, although survival and rooting of cuttings of other species in the frames alongside the one used for this experiment showed excellent survival and rooting.

Humidity in the frames was probably the depressing factor. It appears that the daily watering of the medium did not supply enough moisture to the slash pine cuttings to offset the transpirational loss. Also, bases of slash pine cuttings become sealed over with oleoresin soon after collection and slowed the intake of water. Throughout the experiment the sand was kept moist rather than thoroughly drenched. These results indicate that the moisture-sand relation recommended by commercial plant propagators for most plants does not supply enough moisture for the successful rooting of slash pine cuttings.

None of the chemical treatments showed any effect, as the suboptimal environment greatly overshadowed any possible beneficial effects of the chemicals. All cuttings were dead 10 weeks after planting, and only five of the cuttings which did not receive the storage treatment had callused bases. In one cutting, small root initials had formed, but the roots were not well developed. Results from cuttings receiving storage treatment verified the information obtained in Experiment 1. The 2-week storage period in the moss had stimulated callus formation on most of the cuttings.

The weather during most of the experiment was very sunny and no additional heating was necessary in the greenhouse; therefore, no bottom heat was supplied to the rooting chamber. The low temperature of the medium might account for the poor callusing of the cuttings. The cumulation of unfavorable moisture and temperature effects probably are responsible for the over-all low survival obtained in this study.

Conclusion

Results of this study indicate that this type of closed propagation frame, used very successfully to propagate numerous types of cuttings, is not suited for rooting slash pine cuttings.

Experiment 4. Response of Slash Pine Cuttings to High Humidity and Constant Water Supply

Water is available to the cuttings at all times when they are placed with their bases in a coarse medium which is flooded. When the atmosphere surrounding the needles is saturated, the water lost by transpiration is decreased considerably. The results of Experiment 3 indicated that an inadequate supply of moisture weakens the cuttings and causes them to dry out in less than 10 weeks. If slash pine cuttings are maintained under high-humidity conditions, they might survive long enough and strike roots. This approach was tested in this study.

Two sets of 20 cuttings each were planted in clay cups filled with coarse gravel and water. One set of 20 cuttings was covered over with large beakers to maintain a high humidity around the needles. The clay cups were kept filled with water throughout the experiment. A thick layer of sphagnum moss was placed over the gravel to make an effective seal for the beakers (fig. 9). The cuttings were kept in the greenhouse.

Figure 9.--Arrangement of slash pine cuttings in clay cups. The cuttings were planted in gravel and a layer of sphagnum moss was placed around the cuttings to seal in the moisture. The environment inside the glass beaker provided good growing conditions, as the sphagnum moss added considerable growth during the course of the experiment.

Results

There was no difference in survival for the two groups planted in the clay cups and none of the cuttings produced roots. The over-all survival of cuttings planted in clay cups was less than for cuttings planted in the propagation benches. Callus formation was negligible, and rotting of the bases was worse than usual. Normal callus formation requires cell division which is accompanied by intensive respiration. Sufficient amounts of oxygen around the point of wound healing are necessary to form the new tissues. Shippy (1930) demonstrated that in apple cuttings and apple grafts respiration ceased and cell division stopped when no oxygen was available. Normal callus formation occurred on apple cuttings when there was at least 14 percent of oxygen in the atmosphere; callus formation was slowed up when the concentration dropped below 12 percent. Zimmerman (1930) also showed that oxygen was necessary for the formation of roots in Salix.

Several of the cuttings were able to stay alive for a 12-week period, which would indicate that the cuttings obtained enough moisture through their bases and lower stems. Part of the bases of cuttings, which otherwise appeared very healthy, had started to rot. This partial rotting might have helped to offset the seal against moisture resulting from the accumulation of gum at the wound. Water can move with less resistance through recently-killed tissue than through living cells (Kramer, 1938). Covering the cuttings with large beakers provided a favorable environment for growth. The sphagnum moss started to green up soon after planting and by the end of the experiment had added considerable growth. This environment, however, did not favor the survival of cuttings.

Conclusion

Subirrigation of the bases of the cuttings does not show any promise for providing a favorable rooting environment for slash pine cuttings. The supply of oxygen for satisfactory cell division is probably at a minimum, and no further work is planned with a subirrigation system unless the water can be artificially aerated.

Experiment 5. Effect of Propagation Media on the Survival of Slash Pine Cuttings Collected During the Month of February

Results of the four previous studies indicated that physical factors of the environment are extremely important in bringing about survival of slash pine cuttings. Control of the environment during rooting is most important to keep the cuttings alive. The results of Experiment 2 clearly indicated the beneficial effect obtained by the addition of vermiculite to the rooting medium. Only one mixture of vermiculite was used in that particular study. Mixtures with a higher percentage of vermiculite might give still better results. This study was designed to test the effect of four different vermiculite mixtures on the rooting of slash pine cuttings collected during the early part of February. No attempts had been made previously to root slash pine cuttings in the greenhouse during the month of February. This time of the year might be opportune for collecting cuttings because active growth has not yet started and all the stored material might be in a readily available form. Active growth of slash pine begins during the latter part of February in the area of Lake City, Florida.

Review of Literature

As mentioned in Experiment 2, vermiculite had been used successfully in rooting studies. It provides good aeration, along with adequate moisture-holding capacity.

Dorman (1947) used continuous fluorescent light in one of his rooting experiments with slash pine cuttings. He reported a slight increase in the number of rooted cuttings, but added, "the effect of light on rooting was not great and was difficult to interpret because of the variation in chemical treatments."

Ferbam is an effective fungicide under some conditions and it is not very toxic to plant tissue. Further, it will not be leached out too quickly from the medium, as it dissolves only slowly in water. It has been reported that this fungicide materially aids in rooting some types of cuttings (Watkins, 1952). Duffield and Liddicoet (1949) used ferbam in rooting the hybrid Pinus attenuradiata. They dipped the basal ends of the cuttings in ferbam powder before planting.

Experimental Procedure

On February 10, 1953, cuttings were collected from ten 20- to 25-year-old slash pines growing in an old field. The male and female flowers were fully developed and only sterile branches were collected. They were trimmed to a length of 5 inches and were planted without any chemical pretreatment. A randomized block design was used having 2 blocks with 30 cuttings per treatment. Two thermostatically controlled heating cables were placed in the bed to maintain a uniform bottom heat of 85°F. The rooting media tested were: (a) 1-1 fine sand-vermiculite mixture, (b) 1-3 fine sand-vermiculite mixture, (c) 100 percent vermiculite, (d) 1-1 coarse sand-vermiculite mixture.

Plastic sides 18 inches in height were mounted around the beds to reduce drift of spray and maintain a more uniform microclimate around the cuttings (fig. 10). Throughout the experiment, the automatic spray system was in operation and the cuttings were covered with a fine spray for 2 minutes out of every 10-minute cycle during the period of 8 a.m. to 6 p.m.

Figure 10.--Environment of cuttings in Experiment 5. The plastic wall around the sides prevented the spray from drifting, and the overhead fluorescent light fixture supplemented natural light and supplied light to the cuttings for a 23-hour period each day. The nozzle in the upper left corner was the type used in the study.

The glass roof of the greenhouse was painted white to exclude direct sunlight, but the cuttings received supplemental light from a fixture containing two 100-watt daylight bulbs. The supplemental light period was started three weeks after planting. This 3-week period was used to allow the cuttings to overcome the initial shock and cut down on respiration. A 1-hour dark period was given to the cuttings during the middle of the night. This dark period was considered necessary, as various other plants require a dark period to complete their metabolic activities.

The cutting bed was treated with ferric dimethyl dithiocarbamate (ferbam) to reduce the fungal attacks on the cuttings. The ferbam powder was thoroughly mixed with water at the rate of 2 level tablespoons per gallon and this suspension was sprayed over the beds during the early morning at 2-week intervals.

Results and Discussion

Survival was fair during the first 6 weeks and no evidence of fungus attack was apparent. After being planted for a period of 6 weeks, a large percentage of the cuttings started height growth, and several cuttings developed succulent shoots up to 4 inches in length. Dorman (1947) reported a similar response for cuttings planted under fluorescent light; in his experiment, cuttings planted under fluorescent light began top growth before those without supplemental light showed any indication of bud swelling. The temperature in the greenhouse rose very rapidly after the first several weeks and reached 95°F. on several occasions. Attempts to lower the temperature by spraying the glass and opening all windows failed. The high air temperature, along with the supplemental light, forced the cuttings out of the dormancy stage, and a large percentage of the stored carbohydrates were used in this initial spurt of growth.

The weakened cuttings died very rapidly after height growth started, and at the end of 12 weeks only 8 cuttings out of a total of 240 were alive. It was impossible to make a valid statistical analysis from such meager data. All the cuttings which were alive after the 12-week period had well-developed callus growth covering their bases. Data on survival are given in table 10 of the appendix.

Survival in the various media was probably influenced to a greater extent by the physiological condition of the individual cuttings than by the physical condition of the medium. Data on early survival rates indicated a more favorable environment for cuttings planted in pure vermiculite. Survival in pure vermiculite was 83.3 percent after 6 weeks, whereas survival in the two media containing 50-percent vermiculite was 47.5 percent.

The ferbam applications kept the fungus population at a relatively low level, no hyphae were observed in the medium.

The plastic walls mounted around the bench apparently maintained a uniform microclimate around the cuttings, since there was no evidence of drying in the rows of cuttings planted along the edges of the bench. Evaporation from the needles was slowed down. There was little air movement around the cuttings, even though the side windows of the greenhouse were open most of the time to keep the air temperature as low as possible.

Conclusion

The findings of this experiment indicate that the early part of the month of February is not a good time to collect slash pine cuttings for propagation in the greenhouse. However, there are many factors which make the interpretation of the results difficult. One of the more important factors is the variation under which the cuttings are rooted. Month of collection and temperature in the greenhouse were confounded

and the effect of each could not be isolated with the facilities available. If the experiment could have been carried out in a greenhouse equipped with an air-conditioning system, the effect of time of collection probably could have been isolated. Under present conditions no cuttings should be collected from selected slash pine trees during the early part of February.

Experiment 6. Survival of slash pine cuttings collected during the period of August 21 to December 11

In the literature review on vegetative propagation by rooting, the fact was brought out that time of year has a significant effect on survival of cuttings. The best time to collect cuttings varies from species to species and with different geographical locations. There are two general seasons in which cuttings can be collected. One of these is during the active growing season when the tissues are succulent. From past studies (Schopmeyer, 1943; Dorman, 1947) it appears that this period of the year is unsatisfactory for slash pine.

The other period to collect cuttings is during the dormant season. At this time twig elongation has ceased, and the winter buds have been laid down. No systematic study has been made with slash pines to determine the optimum period for collection during the dormant period, but Dorman (1947) obtained best results with cuttings collected during October and the early part of November. Cuttings collected during the latter part of the dormant season (Experiment 5) survived poorly. Because time of collection has an important effect on survival of slash pine cuttings, collections were made at biweekly intervals from August 21 to December 11 to determine the effect of season on the survival of slash pine cuttings. For this study, survival after a 60-day period in the propagation beds was used as an indication of their ability to survive in a favorable environment.

Experimental Methods

At 2-week intervals, 6 cuttings were collected from each of 10 trees in a 20- to 25-year-old natural stand. The trees were numbered in the field and the identity of the cuttings was maintained throughout the experiment. The cuttings were not treated, but were planted in a 50-50 mixture of sand and vermiculite immediately after collection. The design in the greenhouse called for two randomized blocks. Three cuttings from each tree were planted per block for every collection period. The first collection was made on August 21, 1953, and the last series of cuttings was collected on December 11. The rooting medium was freshly prepared for each series of cuttings to provide as uniform a rooting environment as possible. Bottom heat of 80 to 85° F. was supplied by thermostatically controlled heating cables. The cuttings were sprinkled by the overhead watering system for 1 minute out of every 10-minute cycle from 8 a.m. to 5 p.m.

A weather station was set up in a clearing next to the ten selected trees. Records on temperature, relative humidity, and rainfall were kept during the period of collection.

Results and Discussion

Weather conditions during the period from August 21 to December 11 were average for the season, except that rainfall was above normal for this region. The average weekly precipitation was 1.44 inches. During the entire period of collection there was a surplus of available soil moisture.

The data on survival (table 11 of the appendix) are summarized in figure 11, where survival after the 60-day period is plotted against date of collection. An analysis of variance of these data indicated a highly significant effect due to the time

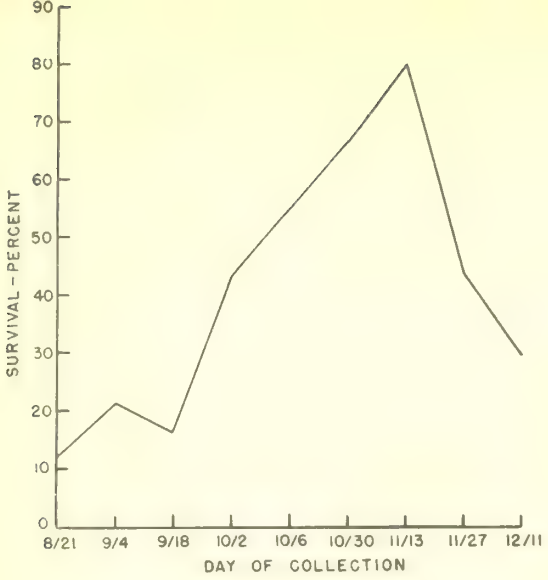


Figure 11.--Effect of time of collection on survival of slash pine cuttings.

of collection (table 4). The average survival increased from 11.7 percent for the August 21 collection to 80 percent for the collection of November 13. After this latter collection the survival capacity dropped very sharply and only 43.3 percent of the cuttings collected on November 27 were alive after the 60-day period.

It is interesting to observe that the first frost of the season occurred on November 27, the date on which the sudden drop in survival began. Cuttings collected on or after this date showed a considerably lower survival. Although freezing temperature is probably not the sole reason for this poor survival, it is felt that in future studies with selected slash pines, cuttings should not be collected after the first frost. The poor survival during the early part of the collection period was probably due to the growth activities of the cuttings at the time of collection. Most of the buds were elongating, as indicated by the white tips.

Table 4.--Analysis of variance of effect of time of collection on survival of slash pine cuttings. Data on number of cuttings alive after a 60-day period were transformed by the angular transformation (Bliss, 1937)

Source of variation	Degrees of freedom	Mean square
Block	1	82.733
Time of collection	8	422.956***
Error	8	19.262

*** Exceeds mean square error, 0.1-percent level of significance.

The internal conditions of the cuttings changed during the period of collection. This accounts for part of the variation in survival. In addition to the physiological conditions within the cuttings, the environment in the greenhouse changed progressively. The warming up inside the greenhouse was gradual because the glass had been painted white and the temperature in the beds was maintained by thermostats.

There was strong evidence of clonal variation between the 10 trees selected. Cuttings from tree No. 8 survived poorly, and all cuttings from the first four collections died within the first 30 days after collection. Clonal variation in slash pine had been reported before by Dorman (1947) and Downs (1949). Cuttings from tree No. 8 appeared healthy at the time of collection but yellowing of the needles began soon after they were placed in the beds. The poor survival of cuttings from this tree could have been caused by fungi present in the cuttings at the time of collection. However, cuttings from other trees planted next to cuttings from tree No. 8 did not show any adverse effect. If a fungus had been the causal factor, cuttings clipped with the same cutter as those from tree No. 8 would have been contaminated. Since, this was not the case, indications are that this variation was probably of a genetic or nutritional nature.

Conclusion

The period when slash pine cuttings were collected had a highly significant influence on the percentage of cuttings alive after a 60-day period. Cuttings for propagation in the greenhouse should be collected during late October and early November.

Experiment 7. Effect of Indolebutyric Acid and Ferbam Treatment on Slash Pine Cuttings Planted in Eight Different Media

It was found in previous studies that the environment in which cuttings are placed has a great influence on their survival. A beneficial effect was obtained in Experiment 2 by adding vermiculite to the rooting medium. Ferbam applications to the cuttings in the propagation bed (Experiment 5) were helpful in keeping the fungus population at a comparatively low level. In view of these findings, a greenhouse experiment was designed to test the effect of eight different media on the rooting response of slash pine treated with indolebutyric acid and ferbam. If the cuttings could be kept in a favorable environment and protected from heavy fungus attack, treatment of the bases with indolebutyric acid might bring about a higher general level of rooting.

Experimental Methods

During the middle of October, 1953, cuttings were collected from six slash pines which were in the 20- to 25-year age class. Most of the cuttings bore either male or female flowers. They were kept moist at all times from collection to planting in the beds. A total of 80 cuttings were collected from each tree. They were planted at random in the various media. The media contained the following materials or mixtures thereof: vermiculite, peat-moss, builders' sand, turkey gravel, and shredded styrofoam. Styrofoam is a light plastic used by florists to fashion displays. Crushed styrofoam has been used by itself or in mixture with other media to root cuttings (Lipp, 1952; DeWerth and Odom, 1953). In mixture with sand it provides a well-aerated medium.

The needles of the lower 2 inches of each cutting were stripped before the bases were treated. Cuttings were moistened and the basal 1-inch portions were dipped first in 0.8-percent indolebutyric acid (Hormodin 3), and then in 70-percent ferric dimethyl dithiocarbamate (ferbam). The dusted cuttings were planted immediately in the various media in open propagation beds, maintained at a temperature of 80 to 82°F. by lead-sheathed electrical heating cables. The cuttings were watered at weekly intervals with an aqueous suspension of ferbam. Sixteen gallons of 0.75-percent solution were sprinkled evenly over the cuttings, which covered an area of 28 square feet.

The eight types of rooting media were: (1) 100 percent vermiculite, (2) 100 percent shredded styrofoam, (3) 100 percent turkey gravel, medium size, (4) 1-1 styrofoam-sand mixture, (5) 1-1 styrofoam-peat mixture, (6) 1-1 peat-sand mixture, (7) 1-1-1 styrofoam-peat-sand mixture, (8) 1-1-1-1 vermiculite-peat-styrofoam-sand mixture.

The cuttings were planted in 2 randomized blocks with 30 individuals per treatment per block. They were sprayed with a fine mist for 2 minutes out of every 10-minute cycle from 8 a.m. until 6 p.m. Fluorescent light fixtures illuminated the propagation beds for a 16-hour period daily beginning at 8 a.m.

Results and Discussion

The cuttings were left in the propagation medium for a 14-week period. At the time of lifting, most of the tops were green and looked healthy. However, all of the bases had died. The blackish coloration of the bases was typical of that obtained when an excessive concentration of hormones is used. Several of the cuttings had developed

short roots but the cuttings had died. The 0.8-percent concentration of indolebutyric acid and ferbam powder was toxic to the slash pine cuttings. Treatments with the same chemicals either alone or in mixture were beneficial with other species of pine (Doran, 1946; 1952b; Duffield and Liddicoet, 1949). In previous studies with slash pine lower concentrations of indolebutyric acid did not result in higher over-all rooting percentage (Schopmeyer, 1943). From this it appears that the amount of indolebutyric acid necessary to stimulate roots in other pine species cannot be used with slash pine cuttings under methods available at present. The relative effects of the various media could not be evaluated in this study.

An observation of interest was that although the bases of the cuttings were dead, rotting did not extend up the stem. The needles retained their green color throughout the experiment. The effect of ferbam applications was pronounced in that little evidence of fungal attack was present.

Experiment 8. Response of etiolated slash pine cuttings to treatment with a root-inducing substance and a fungicide after basal wounding

During the course of this experiment the effect of etiolating the cuttings before removing them from the tree was investigated. Comparisons were made between cuttings wounded at the base before treatment and those without any wounding. Root-stimulating chemicals were used in mixture with a fungicide.

Review of Literature

Placing the twigs in darkness for a short period prior to their removal from the plant was found to be useful in stimulating root initiation (Priestley and Ewing, 1923). A 2-week dark period gave most satisfactory results with specimens of Camphor during the summer months (Blackie et al., 1926). As a result of this dark period, the growth of the bud meristem was slowed down. Priestley and Swingle (1929) postulated that as a result of this growth retardation the food material in the shoots was utilized to organize root initials close to the cambium layer. Vekhov (1934) conducted experiments with a considerable number of tree species in which he etiolated the shoots two weeks prior to the collection of cuttings. He tried two methods of shading. Most of these studies resulted in failures and only cuttings of Cotinus and Carpinus responded favorably to the etiolation treatment. Toda (1952) covered shoots of selected trees of Pinus densiflora with red and blue cellophane bags to examine the effect of light quality on the rooting ability of cuttings. He obtained better results on two trees when he used red instead of blue paper. He could not ascribe the effect directly to light quality, because the blue paper had weakened some of the cuttings considerably.

Wells (1953a, 1953b) recommended the wounding of bases for best results with Ilex, Acer, and Rhododendron. These species root with difficulty under normal treatment, but good results were obtained by making a "heavy" wound at the base of the cuttings. He removed a thin slice about an inch to an inch and a half long which cut through the outer bark to the cambium. He obtained good results by treating the cuttings immediately after wounding by the powder dip method. He considered that the main value of this wound was to allow a larger area of entry for the chemical treatments.

Thomas and Riker (1950) increased the size of the cut surface by making 1-inch slits both in the bark and in the wood at the base of the cuttings before chemical treatment. One such treatment resulted in 17 percent of rooted white pine cuttings, as compared to only 4 percent of rooting in the controls.

Application of growth regulators by the dust method was beneficial to Norway spruce cuttings collected during November, while application to April cuttings was injurious or had no effect (Grace and Farrar, 1940).

Doran (1952a, 1952b) obtained better rooting response in hemlock cuttings after treatment with the fungicide Phygon XL (50 percent, 2, 3-dichloro-1, 4-naphthoquinone). The treatment was effective when used alone or in mixture with indolebutyric acid. He tested four additional fungicides, but none of these improved the percentage of rooting.

Experimental Methods

The cuttings used in this study were collected during the early part of October 1953, from 10 slash pines growing in an old-field stand. The trees were in the 20- to 25-year age group.

Half the shoots used were etiolated during a 2-week period while they were still attached to the tree. A strip of heavy brown paper 7-inches wide was rolled around the shoots used as cuttings. Paper covered bud and all wood of the cuttings. The upper part of some of the needles protruded beyond the cover. The paper strips were held in place by rubber bands.

The needles were stripped from the lower part of each cutting before it was treated. On half the cuttings a thin slice of bark tissue was removed from the base with a sharp knife. The wound was about $1\frac{1}{2}$ inches long. It cut through the phloem tissue and exposed the cambial layer beneath. The moistened base of each cutting was dipped to a depth of 1 inch into a mixture of 0.10 percent naphthylacetamide, 0.05 percent 2-methyl-1-naphthylacetic acid, 0.02 percent 2-methyl-1-naphthylacetamine and 99.83 percent inert powder (Rootone No. 10). Excess powder was removed by tapping the cutting gently against the rim of the beaker. After the treatment with the growth regulator, the base was dipped in 50 percent 2, 3-dichloro-1, 4-naphthoquinone (Phygon XL). This second treatment did not remove the powder of the first treatment but coated the treated base.

The treated cuttings were inserted immediately in the rooting medium, an equal mixture of sand and vermiculite. The propagation medium was maintained at a temperature of 80 to 82°F. throughout the experiment by thermostatically controlled, lead-sheathed heating cables. A new type of watering system was installed for this experiment (fig. 12). The mist sprayers operated for 2 minutes out of every 10-minute cycle

Figure 12.--Propagation bench in greenhouse. A high degree of humidification was maintained by spraying a fine mist on the cuttings for a 2-minute period out of every 10-minute cycle from 8 a.m. to 6 p.m. The fluorescent light fixtures illuminated the cuttings for a 12-hour period, beginning at 8 a. m.

from 8 a.m. to 6 p.m. The glass roof of the greenhouse was painted white to exclude the cuttings from direct insolation. Fluorescent light fixtures illuminated the cuttings for a 12-hour period, beginning at 8 a.m.

The cuttings were planted in 2 replicated blocks with 30 cuttings per treatment per block. The experiment was designed for a 2 x 2 factorial analysis.

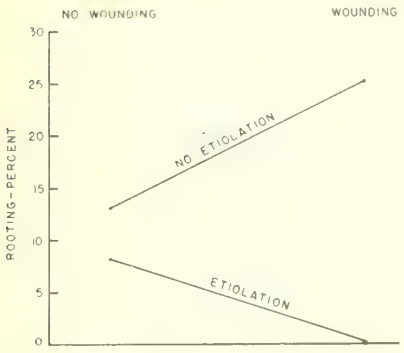


Figure 13.--Effect of etiolation and wounding on the rooting of slash pine cuttings. The average number of rooted cuttings is plotted against the treatment.

Results

The data on percentage of cuttings which rooted are graphically represented in figure 13. In table 12 of the appendix the results on cuttings alive and rooted after a 14-week period in the propagation beds are given. The transformed data on number of rooted cuttings were subjected to analysis of variance (table 5). Etiolating the shoots brought a highly significant reduction in rooting. Effect of wounding depended on the previous treatment of the cuttings. Interaction between etiolating and wounding had a significant effect on number of rooted cuttings. Wounding was depressing on etiolated cuttings, while it was beneficial to cuttings not etiolated. The average for the experiment was 13.3 percent for cuttings not etiolated and not wounded, as compared to 25.0 percent for those wounded and not etiolated. The over-all rooting response was good for the type of cuttings used. The type and number of roots produced per rooted cutting were superior to those obtained in previous experiments. Several cuttings had 5 to 10 roots that were up to 10 inches in length at the time of lifting. Branching of these roots was profuse.

Table 5.--Analysis of variance of number of rooted cuttings after a 14-week period. All data were transformed by the angular transformation (Bliss, 1937)

Source of variation	Degrees of freedom	Mean square
Block	1	22.681
Treatment	3	318.604
Etiolation (E)	1	628.174**
Wounding (W)	1	26.901
E x W	1	300.738*
Error	3	13.158

* Exceeds mean square error, 5-percent level of significance.
** Exceeds mean square error, 1-percent level of significance.

A starch test was made on six etiolated shoots after they were removed from the trees. Thin, freehand longitudinal sections of the wood 3 inches below the bud were prepared. They were placed in hot water for $\frac{1}{2}$ minute, after which they were placed in hot 95 percent ethyl alcohol to dissolve the chlorophyll. After the chlorophyll had been removed, they were rinsed with hot water before being placed in a I_2KI solution. Control sections from cuttings which had not been etiolated were treated in the same manner. The purplish-black coloration was much stronger in these latter sections, indicating a higher starch content. The difference was especially pronounced in the pith and the

region of the cortex and phloem. The indications were that etiolation had partially depleted the starch reserve in the cuttings. This lower level of stored carbohydrates possibly accounted for the poorer results obtained with etiolated cuttings.

The fungicide treatment apparently kept the fungus population at a low level. There was no evidence of rotting around the bases of living cuttings or around the bases which had died.

Discussion and Conclusion

The stimulating effects from etiolation referred to by Priestley and Ewing (1923) were observed in annual, rapidly growing plants, such as broad bean and potato. This type of plant grows considerably during a 2-week period. The new growth laid down in these shoots reflects the environmental conditions under which it developed. The beneficial response to etiolation with these 2 species was explained by Priestley and Ewing "in terms of causal anatomy on the assumption that when the stem apex grows under conditions more normal to the root apex, its development proceeds in a manner more characteristic of the root." The slash pine cuttings were etiolated during the dormant period after the winter bud had formed. The short period of etiolation probably did not effect cell division in the lignified branch.

In addition to lowering the starch content, the tight paper wrap impeded aeration of the needles. Some needle fascicles were killed by the high temperatures which developed along the dark surface of the wrapping. The general over-all weakening, along with a depletion of stored carbohydrates, possibly helps to explain why none of the etiolated cuttings rooted after their bases were wounded.

In many instances, wounding of the freshly collected cuttings resulted in a well-developed root system. Roots were generated along the base and the rim of the wound. It appears that some sort of basal wounding in slash pine cuttings may be promising if the right root stimulants and fungicides are applied.

Root tips became visible after the cuttings had been planted for 6 weeks. This period was shorter than in previous experiments. The early start probably accounted for the healthy, well-developed root-systems. Whether this beneficial effect was due wholly to the hormone treatment or due partly to the beneficial effects of the fungicide is not known. Doran (1952a) speculated that Phygon XL might have hormone-like properties, because the rooting of cuttings was as much improved by Phygon XL alone as by a similar treatment followed with indolebutyric acid.

Etiolation had an unfavorable effect on slash pine cuttings. This technique should be discarded for mature slash pines. The favorable effects of the combined chemical treatment and basal wounding should be helpful in producing rooted cuttings from selected slash pines for progeny testing. With an earlier beginning of root formation, the cuttings are exposed to pathogens for a shorter period; thus the chances of obtaining rooted propagules are enhanced.

Experiment 9. Air-layering of slash pines

One of the important factors contributing to failure of root development in slash pine cuttings is the shock which cuttings sustain when removed from the tree. Large amounts of reserve carbohydrates and other nutrients are needed to form the callus tissue and to develop the roots. Once a cutting is severed from the tree, it has to rely on the nutrients stored before it was severed.

In air-layering, the branches are not removed from the tree, but roots are induced to form on the branches while they are still a part of the parent plant. After the roots have developed, the branch bearing these roots is severed from the original plant

and handled as a separate individual. As in any other asexual method of propagation, layering reproduces a plant with the identical genotype of the original plant.

This study was carried out to find out whether or not the air-layering of slash pine branches is physiologically possible. No previous attempt in America to reproduce pines by air-layering has been reported. The successful use of the method on slash pine, as reported in this paper, indicates that the technique has real promise for extension to other species which are difficult to propagate by cuttings.

Review of Literature

In nature, layering occurs in a large number of gymnosperms (Cooper, 1911; Lutz, 1939; Bannan, 1942; Vaartaja, 1949) when lateral branches become covered by mineral soil, moist litter, or moss. Natural layering of slash pine branches apparently has not yet been observed in the field, and as far as the writer is aware only one instance of natural layering of pine in America has been reported (Lutz, 1939). In his discussion of an isolated occurrence of a rooted basal branch of eastern white pine, Lutz considered the intolerance of most pines to shade as a possible explanation for this rare occurrence. In pines, the basal branches ordinarily die before they become covered with organic debris. Slash pine trees growing along margins of old fields occasionally have several of their basal branches covered by litter, but no natural rooting occurs.

In layering, the stem or branch is usually wounded by girdling or by scraping the cambium to inhibit the free movement of plant solutes. The wounding is done either by completely removing a ring of bark or by cutting a tongue which can be kept from healing by inserting a piece of wood (Watkins, 1952). If the wound is covered with moist, sandy soil, roots will develop in many plant species.

A method of layering where roots are induced to form on a place not in contact with the ground has been in use by the Chinese for some 20 centuries. It is known to the horticulturists as air-layering, Chinese layering, marcottage, mossing off, or vegetative propagation from gootes (Watkins, 1952; Thakurta and Dutt, 1941). A handful of moist sphagnum moss or other moisture-holding material is placed around the stem where the wound is made and is covered over by moisture-proof wrappings.

During 1940 and 1941, Lasschuitt (1950) was able to stimulate adventive root formation of Pinus Merkusii by marcottage. This species of pine grows in the tropical forests of Sumatra and occasionally produces spontaneous adventive roots in wounded or damaged trees. Lasschuitt reported a "spontaneous" case of rooting in which 30 to 40 roots had developed along the wound of a split tree fork. Several of these roots had branched and were over 3 feet in length. These observations prompted Lasschuitt to start a rooting study in which he rubbed mechanical wounds with a mixture of leaf-mold and "pine-soil" containing mycorrhiza. Then the wounds were packed with 5 to 10 kilograms of this mixture, kept in place by a mat. These marcottes had to be watered during the dry season. After 8 months, 7 of the wounded branches out of a total of 75 had formed roots.

In air-layering, the medium has to stay moist at all times. Frequent watering of the wrapping was one of the big chores until the newer plastic films became available. Polyethylene films have properties which make them suitable to cover the moisture-holding wrap in air-layers (Wyman, 1952). Among these desirable properties are the high permeability to gases like oxygen and carbon dioxide, the very low permeability to water vapor, and the transparency of the film. Because of the latter quality, the root formation of the twig can be noted without disturbing the wrapping.

Wyman (1952) presented a large list of plants that root with difficulty but responded well to the air-layer technique. No member of the genus Pinus was included in this list, but several of the forest trees considered "difficult" to root as cuttings responded

satisfactorily to the air-layering technique. Wyman's experiments, however, had to do only with the formation of visible roots. He did not attempt to solve the problem of cutting the potential plants from the parent and getting them to grow after they were potted. His few attempts to pot these plants were unsuccessful.

Treatment of the wound with growth regulators gave promising results in the air-layering of 2- and 3-year-old mango plants (Thakurta and Dutt, 1940; 1941). Roots were found in the treated regions within 6 weeks of treatment, whereas there was no rooting in the untreated control plants. Root induction on the branches treated with auxin of older mother plants was successful, but the time taken for root formation was comparatively much longer and the number of roots produced was much less than on the younger trees. The roots which formed on the older trees were quite insufficient for the independent existence of the goote in the soil. In a later study Singh (1953) succeeded in air-layering shoots from 30-year-old mango trees. The rooted shoots developed normally after they had been detached from the mother plant and potted.

Several organizations and institutions have started experiments with this technique since a preliminary report of the results with slash pine was published (Mergen, 1953b), but no results from these studies are available as yet. Professor David (1953) also used the method successfully to root maritime pine.

Design of Experiment

A total of 52 air-layers were made on 26 slash pines. The first set of 8 was prepared on October 22, 1952, the second group of 20 on May 15, 1953, and the third group of 24 was prepared on August 7, 1953. Only a small sample of plastic wrapping material was available at the beginning of the study, which accounts for the smaller number of attempts in October, 1952. The starting dates were staggered to determine the optimum time of year when air-layering should take place.

To obtain information on the beneficial effect of indolebutyric acid, paired groups were used in the experiment. Relative position of the branch on a tree has a pronounced effect on the rooting response of the branch, and to overcome this difficulty, two branches growing from the same whorl were selected for the comparative air-layering on each tree. Half the wounds were treated with indolebutyric acid, while the other half were not given any chemical treatment. The environmental conditions for the two groups were equivalent except for the factor specifically under test, and the chemical treatment was allotted to the two groups at random.

All air-layering was attempted on natural slash pines between the ages of 5 and 17 years. The branches ranged in diameter from 1/4 to 3/4 inch and some were up to 24 inches in length.

Air-layering Procedure

Slash pine branches selected for rooting were prepared by first stripping the needle fascicles from the lower part of the branch. A 1/4 to 1/2-inch ring of bark and cambium was removed with a sharp knife at the place where root formation was desired (fig. 14A). The wounded area was scraped clean of any remaining cambium cells. Incomplete removal permits callus material to bridge the wound, thus preventing root formation. The upper rim of the girdle on one-half of the branches was dusted with an 0.8-percent indolebutyric acid mixture in talc (Hormodin No. 3). A handful of moist sphagnum moss was wrapped wround the treated part (fig. 14B) and covered with moisture-proof plastic. The moist sphagnum moss was squeezed before it was wrapped around the completely girdled cut. Commercial "Airwrap" was used as covering material [3/] in these tests. The film was fastened at the top and bottom with grafting tape (fig. 14C). The plastic film covered the sphagnum moss and no opening was left for the evaporation of moisture from the moss. If properly applied, the moss in the air-layer stayed moist for several months. If drying became noticeable, a little water was added with a hypodermic syringe.

3/ "Airwrap" is a moisture-proof, gas-permeable plastic treated with a water-soluble emulsion of nutrients, hormones, insecticides, and fungicides.

Figure 14.--Air-layering a slash pine branch. A, A ring of bark and cambium was removed. B, After the wound was scraped clean, a handful of moist sphagnum moss was wrapped around the girdle. C, A moisture-proof, treated plastic sheet was wrapped around the ball of moss and fastened tightly at the ends with grafting tape.

Results and Discussion on Air-layering

The results on adventitious root induction are presented in table 6, where data have been assembled by time of year and chemical treatment. The time span for the first root formation is also given. The statistical analysis of the paired data, using a "t" test, indicated a highly significant effect of the indolebutyric acid on the number of roots produced. The average number of roots developed for all attempts, including the unrooted branches, was 5.58 for the treated branches, whereas only 1.46 roots were produced by the untreated air-layers. A Chi square analysis of the data on number of branches rooted indicated a beneficial effect of chemical treatment which was significant at the 5-percent level. The data were corrected for continuity before they were subjected to the Chi square analysis procedure.

Table 6.--Effect of indolebutyric acid on root development in air-layered slash pine branches

Date started	Treated indolebutyric acid			Untreated			Time elapsed for first root development
	Attempted	Rooted	Average roots per branch	Attempted	Rooted	Average roots per branch	
	Number	Number	Number	Number	Number	Number	Weeks
Oct. 22, 1952	4	3	4.3	4	0	0	23
May 15, 1953	10	8	5.2	10	6	1.6	8
Aug. 6, 1953	12	11	8.1	12	7	4.0	6

Average rooting percentage was 84.6 for the treated branches, whereas only 50.0 percent of the untreated branches rooted. The data on number of roots produced are a much better indicator of the effect of treatment, as in many instances the number and quality of roots produced without the indolebutyric acid treatment would not have been sufficient for the branch to stay alive once it had been removed from the plant and potted. The diameter of the roots on the untreated branches was much smaller and the root tips did not appear as vigorous as those of the treated ones.

The branches which were air-layered during October produced the first roots after 23 weeks. These branches became semidormant soon after girdling, and root initiation probably took place at the start of the next growing season.

The first group of air-layers which had been started on October 22 were checked periodically, and the first roots were observed on March 30, 1953, five months after the start of the test. A collar of callus tissue had formed along the upper rim, and ten roots had developed from it. Most of the roots were located along the lower side of the branch (fig. 15), indicating the polarity of the root-forming substances. Some of the roots were as much as 2 inches in length. They were stiff and stout, and several of the larger roots had started to form side branches. There was no evidence of fungi or other damaging microorganisms around the newly developed roots.

In most air-layers the greater number of roots was on the side receiving the largest amount of sunshine. As light could not penetrate through the wrapping material to the wounded area, it would appear that the higher temperature of the medium was the active factor. As a result of the higher temperature, cell division and cell differentiation were probably stimulated. This in turn resulted in more prolific root development. In rooting experiments, a relatively high temperature of the medium was found to promote a better root system (Price and Hurd, 1932).

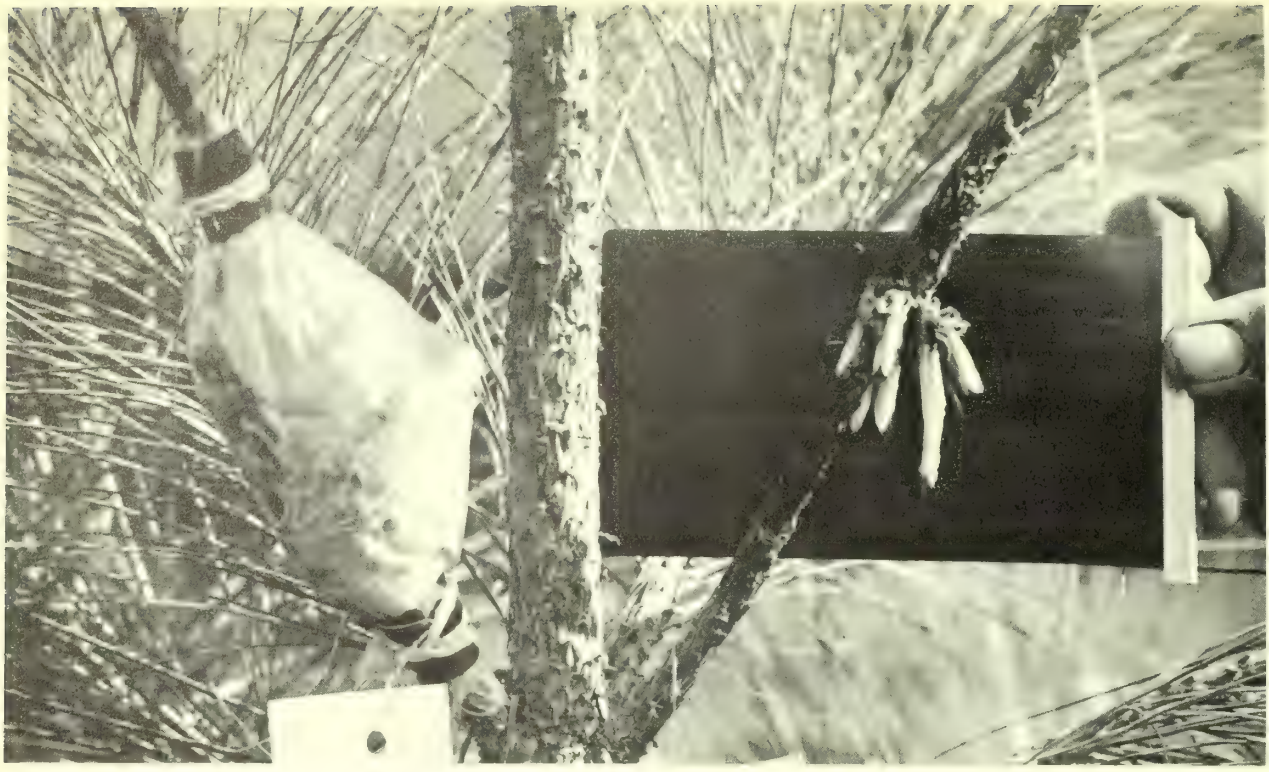


Figure 15.--Roots on air-layered slash pine branch. This branch had a total of 10 separate roots, most of which had developed along the lower side of the branch.

Observation of the bud or shoot development of the air-layered branches frequently indicated the success or failure of the rooting attempts. In one instance, for example, the terminal bud on the branch which had rooted was still in a dormant stage, while a new shoot 6 inches in length had developed on the branch which had not formed roots (fig. 16). Both branches started from the same whorl on the same tree. Many similar instances were observed, but the example illustrated showed the greatest difference in growth pattern.

It is possible that a growth inhibiting hormone is produced near the callus tissue and translocated to the apical growing point, or that treatment inhibited the buds (Thimann and Delisle, 1939). Once the branch was cut from the tree, potted, and watered with liberal doses of a soluble fertilizer mixture, height growth followed without delay. Thus the delayed height growth was probably of a nutritional rather than an auxin nature. The stored food materials had been utilized to develop adventitious roots rather than to add a new shoot. The difference in growth pattern was most pronounced where roots formed only on the branch which had received the indolebutyric acid treatment. This observation is in agreement with Loeb's (1924) findings regarding the drain of food supply by the new growth. He found the drain of available food supply to be of the same effectiveness for equal amounts of new growth, whether the growth was centered in the shoot or in the roots.

Root Formation

By the periodic examination of the wound surface some insight was gained as to the manner in which the adventive roots were formed. For the most part local swellings occurred along the rim of the wound closest to the branch tip. The first callus formation could be observed about 10 days after treatment. At first the swellings appeared as isolated dots but expanded rapidly. Within several weeks they had fused together to form a solid callus rim. The first callus appeared from the phloem region.

Figure 16.--Comparison of height growth between rooted and unrooted branch. Branch on right-hand side of photograph (still attached to stem) did not root but added 6 inches of height growth (A). The rooted branch on the left grew from the same whorl. It had been treated with indolebutyric acid. The terminal bud remained dormant.

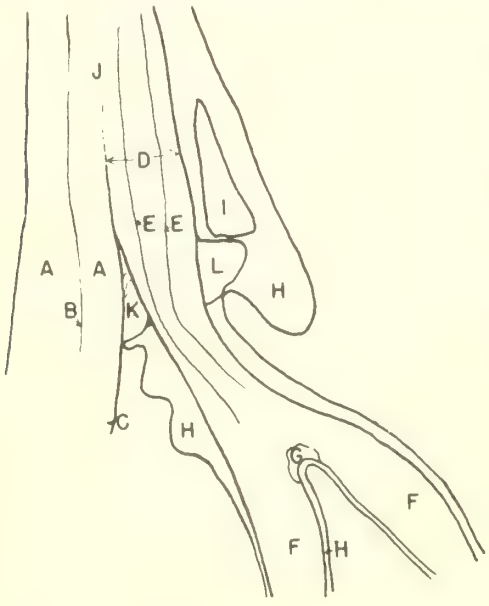
It was whitish in color and turned brown as suberization occurred. The rim closest to the main stem did not add any noticeable growth. It appeared to die rather than develop a protective callus cushion. There was a marked swelling at the basal end of the air-layered branch just above the girdle. White protuberances became noticeable on the upper rim of both the treated and untreated wounds. On the untreated wounds, however, they did not elongate to the same extent as on the treated areas. The chemical substance which brings about differentiation of the callus tissue was probably lacking in the untreated wounds.

White protuberances on the callus surface were the first indications of root formation. But not all protuberances of the callus contained root primordia. Some consisted entirely of parenchymatous cells resembling those in the other parts of the callus, while in the other swellings distinct root primordia were visible. The outward appearance of these two types of protuberance was similar, and the types could only be identified after dissection.

Origin of Roots

In conifers, adventitious roots originate from various sectors of the stem. Ten rooted air-layered branches were dissected to observe the origin of the roots to see if a certain sector of the stem involved a greater number of roots. Bannan (1942) observed that the adventitious roots of larch originated in the vicinity of dead or injured dwarf branches. In spruce and fir the roots arose from dormant buds, while in ground hemlock they arose from sectors of the cambium comprising variable numbers of fusiform initials and the intervening ray initials. He made his observations on adventitious roots which had formed spontaneously in nature. Mechanically or chemically stimulated roots probably do not follow such a regular pattern. If, however, most of the roots arose from a certain sector of the slash pine branches, this knowledge would be helpful in preparing the girdle.

Examination of the differentially stained (safranine--fast green--orange G) free hand sections invariably showed that the roots arose from the basal part of the upper section of the girdle. There were continuous vascular connections between the xylem of the roots and the xylem or secondary tissue of the branch which had been produced by the wood cambium after the girdling. Figure 17 is a camera lucida drawing of a longisection of the root and part of the stem of a rooted air-layered branch. The wood



LEGEND:

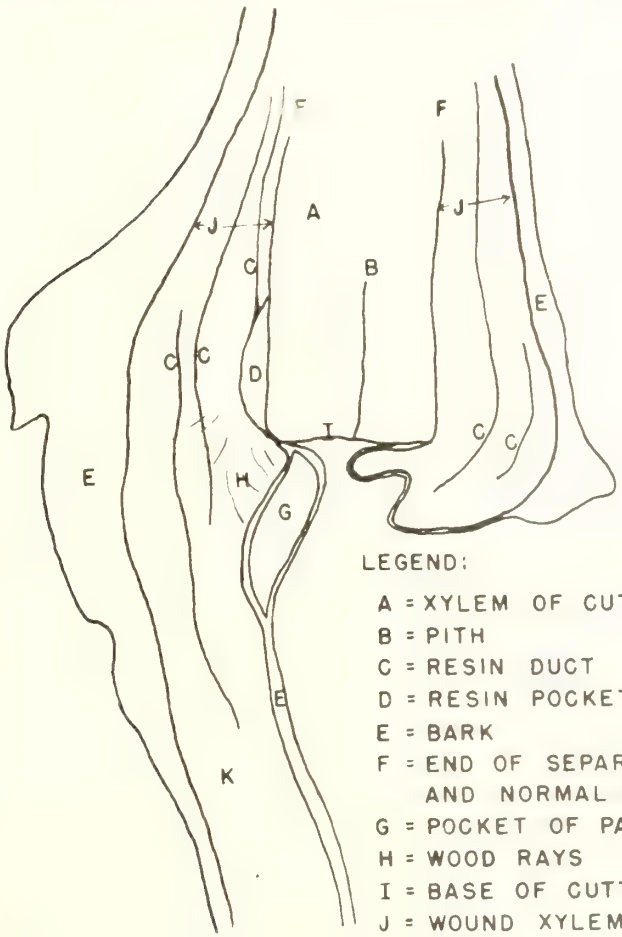
A = XYLEM OF BRANCH BEFORE GIRDLING
B = PITH
C = LINE OF GIRDLE
D = WOUND XYLEM
E = RESIN DUCT
F = ROOT
G = POCKET OF PARENCHYMA CELLS
H = BARK
I = SCALE
J = END OF SEPARATION BETWEEN LAYERS OF WOUND XYLEM AND NORMAL WOOD
K = RESIN POCKET
L = PHLOEM BLISTER

Figure 17.--Camera lucida drawing of radial section of rooted branch (X10).

laid down just above the girdle of the branch accepted the stain to a degree different from that of the xylem which was present before the branch was injured. This particular type of wood was referred to by Sledge (1930) as "wound wood." In the sections examined, it contained a large amount of parenchymatous tissue. The longitudinal resin ducts of this newly laid down wood formed continuous canals into the roots.

A comparison of the root origin in air-layered slash pine branches and in rooted cuttings showed great similarity between the two types of root systems. Adventitious roots in cuttings also originated from the wound xylem or callus rim which had formed after the cuttings were placed in the propagation medium. The vascular connections between the roots and the wound xylem were continuous. Figure 18 is a camera lucida drawing of a radial section through the base of a rooted slash pine cutting. The roots on this cutting were 11 months old.

Observations of the early stages of root formation indicated that the roots arising from the newly-formed wood are endogenous in origin. They arose in the callus or wound tissue. The endogenus nature of adventitious roots in pines was described previously by Deuber (1940) and by Delisle (1942), but a preliminary report on the callus and adventitious root development in Pinus densiflora and Pinus densiflora x Pinus thunbergii by Toda and Satoo (1948) indicated an exogenous origin of these roots. The type of root anlagen above the wound as illustrated by Delisle (1942) was not observed in slash pine. They emerged directly from the callus collar and grew downward. Only abortive roots grew from the callus collar at right angles to the branch.



LEGEND:

A = XYLEM OF CUTTING
B = PITH
C = RESIN DUCT
D = RESIN POCKET
E = BARK
F = END OF SEPARATION BETWEEN LAYERS OF WOUND XYLEM AND NORMAL WOOD
G = POCKET OF PARENCHYMA CELLS
H = WOOD RAYS
I = BASE OF CUTTING
J = WOUND XYLEM
K = ROOT

Figure 18.--Camera lucida drawing of radial section through base of rooted slash pine cutting (X10).

None of the observations indicated that the roots arose from a particular location on the branch. They all originated from the base of the "wound wood" which had been laid down along the lower part of branch above the girdle. This would indicate that the relative position of the girdle is of little consequence as long as it is located in immature tissue which can start prolific cell division and differentiation without delay.

In several instances the amount of auxin powder which was applied to the girdle killed part of the tissue. This did not necessarily interfere with good root formation but the roots were formed above the killed area.

The diameter of the emerging roots was rather large. In some instances it was as much as 5 mm. At first they were whitish in color and at this stage they were extremely brittle. Later they changed to dark brown and became firmer, having the consistency of an orchid tuber.

Planting of Rooted Branches

As soon as good root development was observed through the plastic wrapper, the branch was cut off below the girdle and potted in a loose soil. An equal mixture of sand, vermiculite, and peat was found very suitable for this purpose. After the rooted branches, which were as much as 20 inches in length, were planted in 1-gallon metal cans, they were placed in a humid greenhouse for 6 weeks before they were moved into the nursery. A pint of a 3-percent solution of 7-9-19 fertilizer was added to each pot to stimulate rapid root development. The shock which the branches sustained when they were clipped from the tree was apparently small, as root elongation did not stop. In several instances as much as 4 inches of root growth were added within 2 weeks after potting.

A rooted slash pine branch which was planted during the end of March started height growth without delay, and within 5 months the root growth had filled the space of a 9-inch clay pot (fig. 19). This is in contrast to cuttings which develop in propagation frames. The latter have a tendency to develop more slowly in the beginning.

Figure 19.--Root system of potted air-layered branch. This branch had been potted for a period of 5 months. Root growth was active and mycorrhizae were numerous.

Conclusions

This study has proved that the rooting of slash pine branches by air-layering is physiologically possible. It appears at present that the air-layering method has great possibilities for the vegetative propagation of slash pines. A much greater percentage of rooted branches can be obtained by this method than by bench propagation, and advantage can be taken of the root-promoting chemicals. The initial time involved to prepare the branches is greater than when cuttings are rooted in a propagation frame. But once the branches are prepared, they require no care or attention until rooting has occurred. With cuttings, however, the preparation of the benches and the control of the greenhouse during the rooting period require considerable care.

When slash pine cuttings are collected for bench rooting, they are trimmed to a length of about 5 inches. Branches selected for air-layering can be much longer than cuttings. During this study, branches which were at least twice and in some instances three times as long as cuttings were air-layered (fig. 20). The greater length helps to give the new propagules a rapid start and up to 2 years of height growth can be gained.

In selecting branches for air-layering, sturdy, straight shoots should be used if present. Curved branches will retain their form for some time. With this "new" method it should be possible to obtain clones from the refractory forest conifers for experimental outplantings in forest tree improvement programs.

Figure 20.--Comparison between rooted cuttings and air-layered branch. Rooted cutting on left had a total length (above roots) of 6 inches. Air-layered branch was 16 inches long at the time of preparation.

DISCUSSION AND CONCLUSIONS

The main contribution of the studies on rooting was the finding that slash pine can be propagated by air-layering. By this new and different approach to the problem a greater number of successful propagules can be obtained. The experiments on rooting brought out several important facts which will help to obtain rooted slash pine material for forest tree improvement work. Rooting slash pine cuttings can still be considered in the experimental stage, and results of some of the experiments might possibly form the basis for future research work along these lines.

Time of Collection

Of the factors studied, season of collection appears to be of greatest significance. Cuttings were collected during the dormant season only. At the beginning of the dormant stage survival was low but increased steadily until the middle of November, when a sharp drop occurred. Cuttings collected toward the end of the dormant season, in the early part of February, started growth shortly after they were planted in warm propagation beds. This spurt of growth weakened the cuttings considerably, and they died very rapidly after height growth had started. Thus, late October and early November are apparently the best periods for collecting slash pine cuttings.

In the rooting studies with cuttings, effect of season and environment in the greenhouse were confounded. This makes it difficult to isolate either factor.

The seasonal effects on air-layering were also prevalent. Branches air-layered in August rooted after 6 weeks, while 23 weeks had elapsed before the first roots were visible on branches layered in October. Branches prepared in October entered the dormancy period soon after treatment, and roots were formed only at the start of the next growing season. Best results will be obtained if slash pine branches are air-layered during the summer months. At this time growth is very rapid and frequent rains provide an ample supply of moisture.

Environment in Greenhouse

Slash pine cuttings require a humid environment during the rooting period and best results were obtained when cuttings were sprayed at periodic intervals during the daylight hours. Neither placing the cuttings with their bases in water, nor the use of a closed propagation frame was suitable for rooting. Direct insolation had a detrimental effect on survival but good results were obtained in shaded beds.

Addition of vermiculite to a sand rooting medium increased the average level of rooting. Good aeration along with adequate moisture-holding capacity are necessary characteristics of a good rooting medium. The medium was maintained at a temperature between 80 to 85° F.

Treatment of Cuttings--Physical

Etiolation of shoots, prior to their removal from the tree, gave poor results. The strips of brown paper wrapped around the upper part of the shoot had an over-all depressing effect. Starch content within the cuttings was lowered and the tight paper wrap provided poor aeration around the needles. This particular pretreatment does not show promise with dormant cuttings.

Cuttings responded well to basal wounding prior to chemical treatment. Roots formed along all the wounded areas, and some cuttings had well developed root systems.

It was found undesirable to place the cuttings for a 2-week period in a precallusing box. Most of the cuttings stored in sphagnum moss had started to form callus at the base, but the storage period was not long enough to allow callus growth to cover the wound entirely. Subsequent survival of these cuttings was poor. The environment in the storage box was favorable for fungi. These fungi destroyed the parenchymatous tissue of the basal part of the cuttings before the protective callus growth could cover the wound. This adverse effect could be partially overcome by sterilizing the sphagnum moss. A precallusing period is not necessary when a well-aerated, sterile propagation medium is provided.

Treatment of Cuttings--Chemical

None of the solution treatments tested on slash pine cuttings improved rooting ability. Several of the most promising plant hormones were used in conjunction with vitamins and sucrose. It appeared that environmental conditions were of greater importance than chemical treatments. The rooting ability of cuttings is correlated with their internal conditions. Treatment with root stimulants is effective only if these chemicals are lacking in the cuttings at the time of planting. From these studies it appeared that the concentration of indolebutyric acid which is necessary to stimulate roots in other species of pine is lethal to dormant slash pine cuttings.

Supplementing the nutritional level in the cuttings favored a large number of fungi, which destroyed the meristematic tissue of the cuttings.

Basal treatment by the powder-dip method in Rootone 10 or Phygon XL stimulated root generation. Root tips became visible after a shorter period than for cuttings not treated in the same manner. This is an important consideration, because a shorter period in the propagation beds means a shorter exposure to pathogens.

When indolebutyric acid treatment was used on air-layered slash pine branches, good results were obtained. This chemical treatment, although lethal to slash pine cuttings, was of great benefit to air-layers. It increased the percentage of successful propagules as well as the number of roots per branch.

Treatment of Cuttings--Fungicidal

A suitable rooting environment for slash pines also presents a good environment for pathogens. Applications of ferbam to the propagation beds helped to check fungal activities. Basal treatment with Phygon XL apparently kept the fungus population at a low level.

Dr. A. A. Foster of the U. S. Forest Service [4/] made isolations from the decayed tissues of cuttings and from apparently healthy tissue of cuttings showing no decay. He recovered several bacteria, mucors, penicillia and other saprophytic organisms. Pestallozzia and Fusarium species were the two most common organisms recovered. He felt that if the cuttings remain for a long enough period in a humid propagation bench, they will fall prey to one microorganism or other and indicated that definition of parasitism is difficult.

The best approach to combat loss by fungi is to provide favorable rooting conditions where active meristems can be established in as short a time as possible. Treatment with an effective fungicide is part of such a favorable condition.

4/ Personal correspondence.

Root Formation

In cuttings, as well as in air-layers, roots arise from the callus or wound tissue laid down subsequent to wounding. They are endogenous in origin and do not appear to emerge from a particular region on the branch. This indicates that in air-layering the relative position of the girdle is not important but should be located in young tissue which can establish an active meristem.

Air-layered branches in general have a better balanced root system than cuttings. This is an important consideration because cuttings have a tendency to develop one-sided, unilateral roots.

Variation Between Trees

In one study in particular, there was strong evidence of clonal variation between slash pines. The variation remained pronounced through nine separate collection periods. This feature might make it necessary to modify the methods to render them suitable to individual trees.

Sex of a cutting appeared to have no effect on its survival and rooting ability. Cuttings with either male or female flowers rooted.

General

To root slash pine cuttings, expensive installations appear to be necessary. In outdoor as well as indoor propagation beds, automatic watering timers and heating equipment are indispensable.

With the air-layering method no physical installations are necessary. This makes it possible for smaller experiment stations and forestry schools to carry out experiments in rooting of slash pines and possibly other conifers. Furthermore, propagules which are established by the air-layering method are 2 to 3 times larger than a rooted cutting and thus at least one year of growth is gained. When branches are selected for air-layering, straight shoots should be chosen.

Greenhouse methods are indispensable to obtain propagules from desirable trees which are felled accidently or from plant material collected in distant places and sent to the research center.

Estimation of the Genotype

Some forest tree species can be reproduced on a large scale by the rooting of cuttings. With these species, the rooting method can be used advantageously to mass-produce improved strains for reforestation. With methods available at present, a satisfactory number of rooted shoots of slash pine can be obtained to estimate the genotype but present methods do not lend themselves to large-scale propagation programs. Since slash pine must be reproduced from seed, the establishment of seed orchards for superior trees is the logical way to plan a tree improvement program.

Propagation by rooting is preferred as the method for estimating the genotype of selected trees, because grafted "clones," even if the scions have the same genetical make-up, will not give as true an indication of the potentialities of the trees under test as rooted cuttings. The effect of understock on scion varies with the individuals used and cannot be isolated. One way to minimize or equalize the stock-scion effect would be to graft scions on root-stocks of the same clone. This could be done by rooting a large number of branches from a young and vigorous tree for use as understock.

Rooted cuttings are especially valuable for assembling clones from selected trees for outplanting under different geographic and edaphic conditions. This permits a true comparison of the ortets. Clones from selected high-gum-yielding slash pines are growing in a progeny testing plantation at Olustee, Florida. Cuttings from one selected tree did not root in numerous trials and in this case grafts were attempted and proved successful.

In selecting for resistance to disease or insects, researchers should study the behavior of rooted cuttings. One reason is that rootstock affects the mineral and carbohydrate concentration in grafted scions and thereby may alter the natural metabolism and thus change their anatomical and biochemical make-up. This difficulty is avoided in the case of cuttings growing on their own roots.

When plantations for progeny testing are established by rooted cuttings, it is desirable to collect the cuttings from the selected trees as early in the life of the tree as the traits for which it was selected become apparent. Studies in progress attempt to establish the relationship between characteristics in the juvenile stage and the subsequent performance of mature trees. Results from these studies should help in the selection among young trees for gum yield or other traits, and then cuttings can be collected at a time when high success in rooting is obtained.

Assemblage of Germ Plasm

Forest genetics is based on variations which occur in forest trees. These variations can be of a natural origin or brought about by controlled crosses, chemical treatment, or radiation treatment. Workers in the field of forest tree improvement try to utilize these variations in an effort to develop strains of trees better suited to specific environmental conditions or having superior characteristics such as gum yield, growth rate, disease and insect resistance, form or wood structure. The success of these programs is enhanced if an adequate supply of plant material is available to work with. Under natural conditions, trees with desirable traits mostly appear as scattered individuals over large areas. To use these trees in a planned breeding program is not efficient. A great deal of unproductive travel time is involved in checking on the flower development of these scattered trees. Flowers have to be checked at short intervals so that they can be pollinated at the proper time. By establishing grafts from the selected trees in a confined area, the centralization of the breeding work achieves greater efficiency and gives better results. This plan has been followed to establish grafts of selected high-gum-yielding slash pines and fast-growing slash pines. Besides centralization, this method also affords an insurance against loss of valuable germ plasm should the parent tree be destroyed.

In some cases, specimens of rare hybrids developed in other parts of the world can be secured and established by grafting their scions on native rootstock. This approach was used with success to obtain propagules from hybrids growing at the Institute of Forest Genetics, Placerville, California.

Establishment of Seed Orchards

Once the superiority of selected slash pines has been established by progeny testing, methods for mass production of superior seed of desirable crosses will have to be developed. Seed orchards for controlled crosses or wind pollination will be established. Scions from the promising high-gum yielders have been grafted on potted understock and they will be outplanted in a seed orchard outside the natural range of slash pine or in an isolated area within its range. It will be important to select an outplanting site where no slash pine pollen from outside sources is available.

Facilitating Hybridization Work

The hybrid pine, slash x longleaf, has great promise as stock to reforest the drier planting areas in Florida. Under natural conditions the flowering seasons of slash and longleaf pine do not coincide; longleaf pines flower several weeks after slash pines. The catkins of longleaf pine do not lend themselves to satisfactory forcing in a warm greenhouse; they elongate but will not complete meiotic division. Apparently a substance not present during the early stages of development is necessary for ripening pollen. This difficulty was overcome by grafting scions, which were bearing catkins, on 3-year-old slash pine stock. The grafts were staggered over the rootstock and up to four separate clusters were established on one plant. Viable pollen was obtained by this technique for use on slash pine ovulate flowers.

SUMMARY

The investigations on the vegetative propagation of slash pine consisted of a series of 9 rooting experiments and 4 grafting experiments conducted between June 1952 and February 1954. The object of these investigations was the development of asexual propagation methods for use in forest genetics. Rooting experiments with cuttings were carried out in the greenhouse, where effect of season of collection, various chemical and physical treatments, and different environmental conditions were investigated. Field studies on the air-layering of shoots involved tests of effect of season, and treatment of girdle with indolebutyric acid. The grafting experiments considered the problems of greenhouse and field grafting of dormant slash pine scions as well as grafting during the active growing season. In an anatomical study of slash pine graft unions, the histological changes associated with the formation of a graft union were examined. Potential application of heteroplastic micrografting to the induction of flowers in the primary stage was studied.

The experiments on rooting showed that the best season to carry out the work depended on the method used. If cuttings were collected and placed in a favorable greenhouse environment, best survival was obtained when they were collected toward the end of October and the early part of November. When the shoots were air-layered on the trees, it was found that during the summer months root formation was most rapid.

Neither placing the cuttings in a callusing box nor etiolating the shoots before collection was beneficial. When the bases were wounded before treatment with Phygon XL and ferbam, root formation was stimulated. The roots formed in less time than in untreated cuttings. Solution treatments with mixtures of indoleacetic acid, indolebutyric acid, naphthalenecetic acid, pyridoxine, thiamine, nicotinic acid, sucrose, nutrients, and pentachlorophenate were applied in various ways with no beneficial effect. Solution treatments with traumatic acid, and the use of indolebutyric acid in a powder dip, were not successful. The concentration of 0.8 percent indolebutyric acid, which was effective in stimulating roots in air-layers, was lethal to slash pine cuttings. The use of ferbam and Phygon XL was helpful in keeping the fungus population at a low level.

Slash pine cuttings were planted under various environmental conditions. Best response was obtained when a well aerated medium consisting of an equal mixture of vermiculite and builder's sand was used in conjunction with a misting system.

The advantages of the air-layering method over the rooting of cuttings were brought out. Root formation on both types of propagules are similar in origin and are formed at the base of the wound. Air-layers, however, have a better balanced root system and develop rapidly after being placed in soil.

Greenhouse grafting did not present an overall advantage over field grafting. Type of graft was of greatest importance and the outcome of experiments was dependent upon environmental conditions under which the grafts were kept. The bottle-graft method with dormant scions proved most successful and it can be employed for field grafting without the use of sweatboxes. When succulent material was used, both as a scion and as understock, the cleft graft technique resulted in a large number of successful unions. These latter grafts should be covered with polyethylene bags and kept under full shade until a union is formed. The unions resulting from succulent graft partners are very strong and most satisfactory.

Anatomical sections obtained from young slash pine grafts at weekly intervals during the period when the union was forming did not show any evidence of incompatibility between slash pine scion and stock. Meristematic cells of both stock and scion had started cell proliferation within one week after grafting. After a 6-week period cell differentiation of the newly-formed callus tissue had progressed well and the bridging of the callus layers of stock and scion was complete along several contact points.

Parenchymatous cells of medullary rays, phloem, cortex, and cambium were active in bridging the space between tissues of the stock and scion.

The induction of flowering in 1- to 2-year-old slash pines was attempted by grafting young slash pine seedlings on rootstocks of another species, genus or family. Heteroplastic micrografts were established successfully. However, flowering did not occur within the expected time. The following graft combinations are growing successfully and will be kept for further observations: slash pine on slash pine, on loblolly pine, on pitch pine, on ponderosa pine, on white pine, on Douglas fir, on white spruce, and on Norway spruce. Slash pine grafted on Chamaecyparis survived for 8 months.

Methods developed or perfected are discussed in the light of their application to forest genetics research.

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APPENDIX

Table 7.--Experiment 1. Survival percentage and rooting percentage of the cuttings after 12 weeks

Treatment	Block	Survival	Rooting
		Percent	Percent
Solution 1; 30" Hg; no storage	A	23.3	6.7
	B	26.7	6.7
Solution 1; 15" Hg; no storage	A	16.7	3.3
	B	16.7	3.3
Solution 1; 30" Hg; storage	A	6.7	3.3
	B	3.3	.0
Solution 1; 15" Hg; storage	A	16.7	10.0
	B	3.3	3.3
Solution 2; 30" Hg; no storage	A	13.3	.0
	B	20.0	3.3
Solution 2; 15" Hg; no storage	A	23.3	.0
	B	13.3	3.3
Solution 2; 30" Hg; storage	A	16.7	3.3
	B	.0	.0
Solution 2; 15" Hg; storage	A	.0	.0
	B	3.3	.0
No chemical treatment; no storage	A	20.0	3.3
	B	26.7	10.0
No chemical treatment; storage	A	6.7	.0
	B	0	.0

Table 8.--Experiment 2. Rooting percentage of the cuttings after a 14-week period

Treatment	Block	Rooting
		Percent
(A1) Basal pretreatment; needles in solution; sand	A	20.0
	B	16.7
(A2) Basal pretreatment; needles sprayed with solution; sand	A	3.3
	B	10.0
(A3) No pretreatment; sand (control)	A	33.3
	B	20.0
(A1) Basal pretreatment; needles in solution; sand-vermiculite	A	33.3
	B	36.6
(A2) Basal pretreatment; needles sprayed with solution; sand-vermiculite	A	23.3
	B	23.3
(A3) No pretreatment; sand-vermiculite (control)	A	36.6
	B	33.3

Table 9.--Experiment 3.--Percentage of cuttings alive on four different dates 1/

Treatment	Block	Oct. 31	Nov. 13	Dec. 11	Dec. 25
1	A	100	80.0	20.0	0
1	B	100	52.0	.0	0
2	A	100	76.0	32.0	0
2	B	100	96.0	32.0	0
3	A	100	80.0	8.0	0
3	B	100	52.0	32.0	0
4	A	100	100.0	12.0	0
4	B	100	84.0	16.0	0

1/ Cuttings were planted in a propagation box located in a greenhouse of the University of Florida in Gainesville.

Table 10.--Experiment 5. Survival of cuttings planted in 4 types of media
(In percent)

Medium	Block	Weeks since collection				
		4	6	8	10	12
1-1 fine sand-vermiculite	A	100	56.7	6.7	·0	.0
	B	100	53.3	23.3	10.0	.0
1-3 fine sand-vermiculite	A	100	66.7	10.0	·0	·0
	B	100	43.3	10.0	10.0	·0
Vermiculite	A	100	83.3	13.3	10.0	10.0
	B	100	83.3	13.3	13.3	6.7
1-1 coarse sand-vermiculite	A	100	70.0	13.3	13.3	3.3
	B	100	10.0	6.7	6.7	6.7

Table 11.--Experiment 6. Effect of time of collection on survival of slash pine cuttings. Percentage of cuttings alive after a 60-day period in the propagation beds

Date of collection	Block	
	A	B
August 21	16.7	6.7
September 4	20.0	23.3
September 18	13.3	20.0
October 2	36.7	50.0
October 16	50.0	60.0
October 30	66.7	66.7
November 13	76.7	83.3
November 27	33.3	53.3
December 11	23.3	40.0

Table 12.--Experiment 8. Survival and rooting of cuttings etiolated and wounded at the base before chemical treatment. Data taken after 14-week period

Treatment	Block	Survival	Rooting
		Percent	Percent
Etiolation; no wounding	A	13.3	3.3
	B	20.0	13.3
Etiolation; wounding	A	.0	.0
	B	10.0	.0
No etiolation, no wounding	A	23.3	13.3
	B	23.3	13.3
No etiolation; wounding	A	30.0	23.3
	B	43.3	26.7

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Growth and Prospective Development of Hardwoods and Loblolly Pine Seedlings on Clearcut Areas

by

Karl F. Wenger

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

GROWTH AND PROSPECTIVE DEVELOPMENT OF HARDWOODS AND LOBLOLLY PINE SEEDLINGS ON CLEARCUT AREAS

By
Karl F. Wenger

When natural regeneration is relied upon in the even-aged management of loblolly pine, a stocking survey should be made as soon as possible to find out whether the tract can be left as it is, whether cultural measures are needed, or whether drastic treatment to prepare a fresh seedbed is necessary.

To make a reliable estimate of dominant and potentially dominant seedlings, the owner needs facts on growth and development of pine seedlings and their hardwood competitors. Clear cuttings made in the Bigwoods Experimental Forest[1/] in every year from 1946 to 1952 furnished ideal conditions for getting the necessary information.

DEVELOPMENT OF HARDWOODS AFTER CLEAR CUTTING

Two complementary methods of studying hardwoods were chosen. The first concerned the area occupied by the new hardwood growth in relation to time since cutting, soil characteristics, and seedbed preparation. The second dealt with the height growth and lateral expansion, in relation to the same factors of age, soil, and seedbed, of five species of hardwood sprout clumps deemed the most serious competitors of pine seedlings.

Area Occupied by New Hardwood Growth

The area occupied by the new hardwood growth was estimated on square, 1/10-acre plots by the line-intercept method. Sixty-seven plots were distributed over three soil groups, two soil surface conditions, and several ages of hardwood sprout growth based on time since clear cutting the pine stand. The soil groups were (1) well and imperfectly drained, with friable subsoils; (2) well and imperfectly drained, with plastic subsoil; and (3) poorly drained, with plastic subsoils. All burning was done within 1 year after logging and in late summer, from late August till early October.

1/ Maintained in Hertford County, North Carolina, by the U. S. Forest Service, in cooperation with the Camp Manufacturing Company, Inc. Franklin, Virginia.

Figure 1 shows the trends of hardwood area growth on each set of environmental conditions beginning with an initial coverage of 10 percent, which was typical of fresh clear cuttings in the experimental forest. Pine seedlings are not entirely barred from the area classed as hardwood. Many openings that are too small to measure, and the thin crowns of some hardwoods such as sumac, sassafras and hercules club, admit enough light for rapid growth of pine seedlings (fig. 2).

Notice particularly the effect of fire. Fire increased the growth of hardwood cover on the two well-drained soil groups by about equal amounts but reduced it about twice as much on the poorly-drained soils. Without burning, the hardwood cover grew fastest on the poorly-drained plastic soils, slower on the well-drained friable soils, and slowest on the well-drained plastic soils. After burning, growth was fastest on the well-drained friable soil, slower on the well-drained plastic soil, and slowest on the poorly-drained plastic soil. The increased growth on the well-drained soils probably was caused by the mineral nutrients and nitrogen released from the litter by burning, but the reduced growth on poorly-drained soils isn't explained so easily. Possibly aeration was poorer after burning because these soils are more susceptible to puddling and packing upon exposure.

Growth of Sprout Clumps

The species chosen for individual study were sweetgum (Liquidambar styraciflua L.), red maple (Acer rubrum L.), the red oak group (Quercus spp.), dogwood (Cornus florida L.), and waxmyrtle (Myrica cerifera L.). Eight hundred and forty-nine sprout clumps of these species were distributed, although not equally, among the three soil groups, the two surface conditions (burned and unburned), winter and summer cutting, and were up to 5 years of age.

Mean heights adjusted for differences in diameter of stump and age of sprout are shown in table 1.

For sweetgum, red maple, and the red oaks, the outstanding finding was that burning significantly increased their height growth on the well-drained friable soils. Height growth was not affected by late summer burning on the well-drained plastic soils, and on the poorly-drained plastic soils was significantly reduced only in red oak.

Without burning, these three species responded to soils in different ways, but after burning they all grew fastest on the well-drained friable soils, slower on the well-drained plastic soils, and slowest on the poorly-drained plastic soils. The data for waxmyrtle and dogwood were insufficient for similar comparisons because these species were limited and erratic in occurrence.

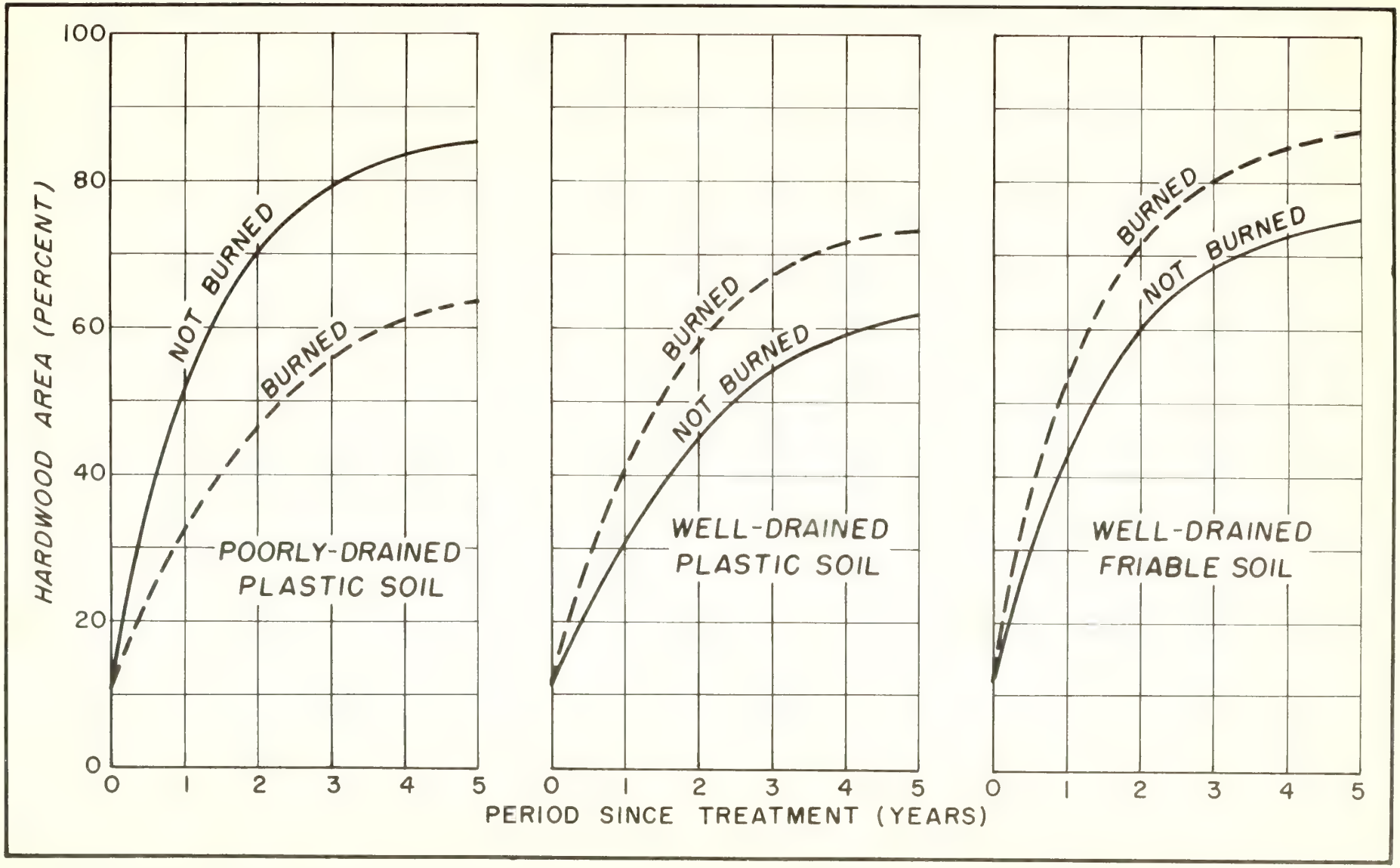

Figure 1.--The increase in area occupied by new hardwood growth in clear cuttings, by soil groups and surface treatment.

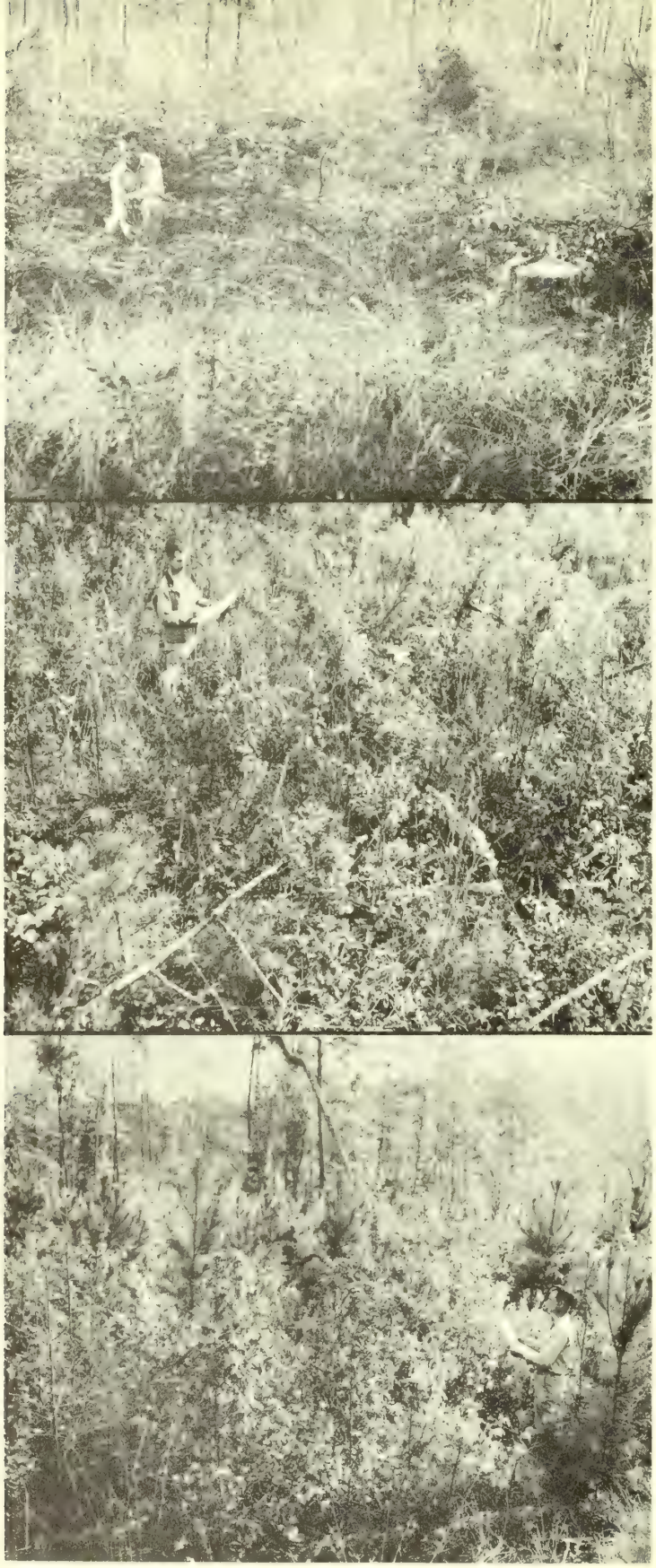

Figure 2.--Vegetation in clear cuttings in the first (top), second, and fourth years after disking and logging.

Table 1.--Mean heights of sprout clumps of five species, adjusted for differences in diameter of stump and age of sprout

Factors affecting sprout growth				Adjusted mean height of sprouts					
Season of:									
Clear cutting	Burning after clear cutting	Surface after treatment	Soil group [1/]	Sweet gum	Red maple	Red oak	Dog-wood	Wax-myrtle	35-acre tracts sampled
				Feet	Feet	Feet	Feet	Feet	Number
Summer	Summer	Burned	WP	3.86	4.28	3.01		2.71	2
Winter & Summer [2/]	Summer	Burned	WF	5.30	4.92	4.39	3.71	2.67	2
Summer	Summer	Burned	PP	3.33	3.57	1.99			1
Summer	None	Not burned	WP	4.74	3.97	2.90	3.94		1
Summer	None	Not burned	WF	4.49	4.18	3.17	3.89	3.17	3
Summer	None	Not burned	PP	4.00	3.58	3.21			1
Winter	None	Not burned	WP	4.77	4.90	3.61	4.52		1
Winter	None	Not burned	WF			6.20	3.84	3.02	1
Winter	None	Not burned	PP	4.71	5.16	3.30			1

1/ WP, well-drained plastic soils.
WF, well-drained, friable soils.
PP, poorly-drained plastic soils.

2/ Two 35-acre tracts clear cut in different seasons.

Wherever a comparison was available, sprouts from winter cuttings grew as fast or faster than sprouts from summer cuttings.

Up to 5 years of age, a 1-inch difference in stump diameter was associated with a difference of 0.5 foot in total height of sweetgum, red maple, and red oak sprouts; 0.3 foot in the height of dogwood sprouts; and 0.8 foot in the height of waxmyrtle sprouts. The majority of stumps were less than 4 inches in diameter.

Crown width and crown height [2/] increased in direct proportion to total height in all species except sweetgum. Therefore, these species retain the sprout clump form at least throughout the first 5 years. In sweetgum one sprout apparently assumes dominance quickly, so that lateral expansion remains practically at a standstill after an initial spurt of growth until a tree-like crown develops on the dominant sprout. Differences in environmental conditions and treatments had no effect on these relations.

The relative frequencies of occurrence of the species with respect to soil groups are presented in table 2. Because length of sampling strips on which sprout clumps were measured was the same for each species, the relative frequency of occurrence in the strips is an estimate of that in the area as a whole. With improved drainage and lighter texture of the soil, sweetgum and red maple become relatively less numerous, and red oaks, dogwood, and waxmyrtle become more so. Particularly notable is the virtual absence of dogwood and the scarcity of myrtle on the poorly-drained, heavy soils.

Table 2.--Relative frequencies of occurrence of sprout clumps of five hardwood species according to major soil groups

Species	Poorly-drained plastic soil	Well-drained plastic soil	Well-drained friable soil
	Percent	Percent	Percent
Sweetgum	41.5	39.0	26.0
Red maple	43.0	39.0	26.0
Red oaks	12.0	10.0	21.0
Dogwood	0.5	5.0	15.0
Waxmyrtle	3.0	7.0	12.0
Total	100.0	100.0	100.0

2/ Height to the widest part of the crown in the vertical plane, where crown width was measured.

DEVELOPMENT OF LOBLOLLY PINE SEEDLINGS

Appearance and Growth of Seedlings

Vigor of hardwood competition is an essential element of the stocking survey. Equally important is the vigor and status of pine seedlings, both dominant and subdominant. In the case of the subdominants we need methods for judging which ones will come through and which ones have little chance.

Figure 3 shows the relation of 1 year's height growth to several seedling characteristics. These relations are based on measurements of 500 seedlings that were not infested by the Nantucket pine moth (Rhyacionia frustrana (Comst.)) and that represented two ages, two soil groups, and burned or unburned soil surface conditions.

The following multiple correlation coefficients show how closely height growth was related to the specified seedling characteristics:

Height-diameter ratio and total height	0.96
Terminal bud length and total height	0.91
Needle length and total height	0.90
Number of branches	0.85

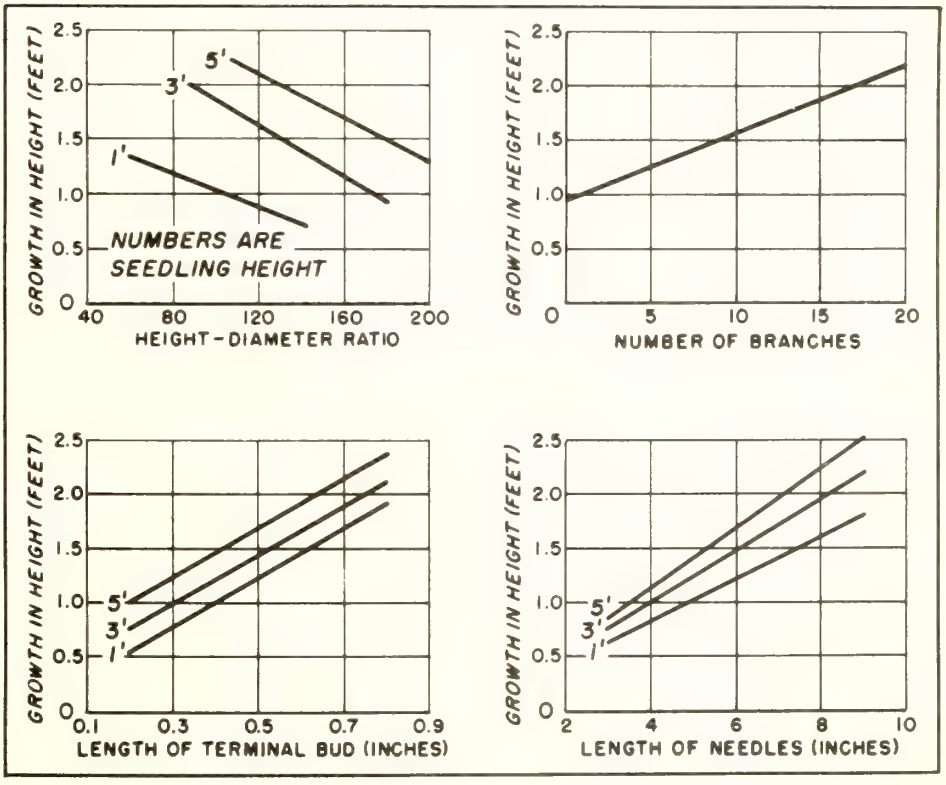

Figure 3.--The relation of 1 year's height growth to the indicated seedling characteristics.

Choice of the characteristic most suitable for field use depends in part on environmental conditions and age. With age taken into account, seedling height should be a good indicator of growth; and, since growth is the combined effect of all factors, past growth should also indicate future growth quite well. Of the four characteristics discussed above, the number of branches was promising for field use because its relation to seedling growth was linear and independent of seedling height and it could be determined without a measuring instrument. The effects of soil and seedling age on the relations of growth to these three seedling characteristics in the second year of the study are shown in figure 4. These effects on the branch and height relations were not significantly different from those in the first year.

The use of branching and seedling height as indicators of future growth is complicated by the influence of environmental factors. Height growth, however, reflects environmental differences in about the same way in one year as in the next. Consequently, the relation of current to previous height growth should be largely independent of these differences as long as environmental conditions do not change appreciably from year to year. The following correlation coefficients show how closely the current year's height growth was related to the specified seedling characteristics in the second year of the study:

Number of branches	0.87
Initial height	0.89
Previous year's growth	0.93

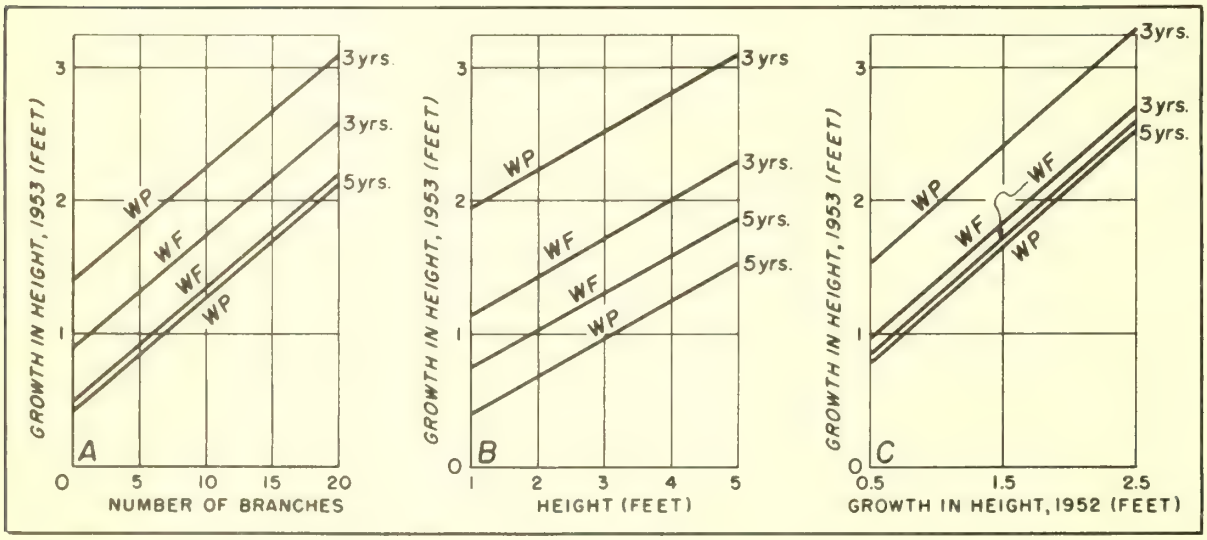

Figure 4.--The effect of soil and age on the relations of seedling height growth to number of branches, initial height, and previous growth.

The coefficient for previous year's growth is significantly higher than those for number of branches and initial height. Thus, of the seedling characteristics studied, past growth is the best criterion of future growth.

Effect of Release

Loblolly pine seedlings respond to release and grow well. Dying seedlings, with prematurely brown needles are, of course, an exception. In a small-scale test a number of 2-year-old seedlings were completely liberated by poisoning overtopping white oak trees with Ammate. The total height, terminal bud length, and color of foliage were recorded prior to release but all released seedlings responded to the treatment and none died (5). In a related study heavily suppressed, low-vigor seedlings collapsed upon release. In a short time they straightened up and grew well. The seedling in figure 5 was 1.7 feet tall and 4 years old when released; 2 years later it was 5.6 feet tall.

Figure 5.--Low-vigor, suppressed seedlings collapse when suddenly given complete release. But they soon straighten up and commence rapid growth.

A less complete form of release involving cutting but no poisoning was also tested. Over 400 4-year-old seedlings were selected in a clearcut area in 1947 and paired according to total height and vigor.[3/] One of each pair was released by girdling large, residual, overtopping hardwoods and by cutting shrub and sprout growth for a distance from the seedling equal to one-half the height of the brush. The released seedlings grew more than the controls under all conditions during the next three years. Height growth alone, however, did not clearly indicate which of these seedlings would become dominant. Therefore, in 1952 the 9-year-old seedlings were classified into two groups, dominant and not dominant, so that the relation between treatment and the attainment of dominance could be examined.

3/ This study was installed by Kenneth B. Pomeroy.

Release significantly increased the percentage of seedlings that became dominant, but the percentage was significantly smaller where an overstory had been present, even though the overstory trees were girdled in the release treatment (fig. 6). Root competition probably was the cause, since the roots were not killed by girdling and were sustained by the sprouts.

Where low competition was light, the percentage dominant was so high that release could increase it but little. Release from heavy competition significantly increased the percentage dominant (fig. 7). However, even with release, less than 60 percent of overtopped seedlings became dominant.

These results show that liberation and cleaning are of doubtful benefit without poisoning to kill the roots so that no vigorous sprouting occurs. This point is further emphasized by the response to release in relation to moisture conditions, of which two distinct kinds existed in the study area. A significantly greater percentage of released seedlings became dominant on the dry site than on the moist site. The difference in control seedlings, although appreciable, was not significant (fig. 8). Sprouts were much more vigorous on the moist site and competed more strongly with the seedlings. Consequently, the response of pine to release was poorer even though the growing conditions were better in the moist area.

Insect Damage

Of the several insects that are commonly found attacking loblolly pine seedlings in the Southeast, the one that foresters are most concerned about is the Nantucket pine moth (Rhyacionia frustrana (Comst.)) usually referred to as the tip moth. Other insects, such as the red-headed pine sawfly, (Neodiprion lecontei (Fitch)), the pales weevil (Hylobius pales (Hobst.)), and the pine webworm (Tetralopha robustella Zell.), occasionally become of concern locally. The tip moth, however, seems to be present in considerable numbers in seedling stands throughout the Southeast at all times.

A single year's attack by the tip moth did not retard the growth of the seedlings. The study of the relation of growth to seedling characteristics was limited to seedlings that had no tip moth attack before the preceding year. Thus the influence of repeated annual attack was not considered in that study. The infested seedlings were located within the same plots as the undamaged seedlings, so that the two kinds were intermingled and subject to identical environmental conditions.

The release study, on the other hand, offered an opportunity to observe the effect of repeated attacks on the growth and dominance of loblolly pine seedlings. The record consisted of the number of years in which a seedling was attacked rather than the specific number of insect attacks. On that basis, each year of attack reduced seedling growth by 0.50 foot; that is, seedlings attacked in 1 year grew 0.50 foot less, seedlings attacked in 2 years grew 1.00 foot less, and seedlings attacked in 3 years grew 1.50 feet less than seedlings not attacked.

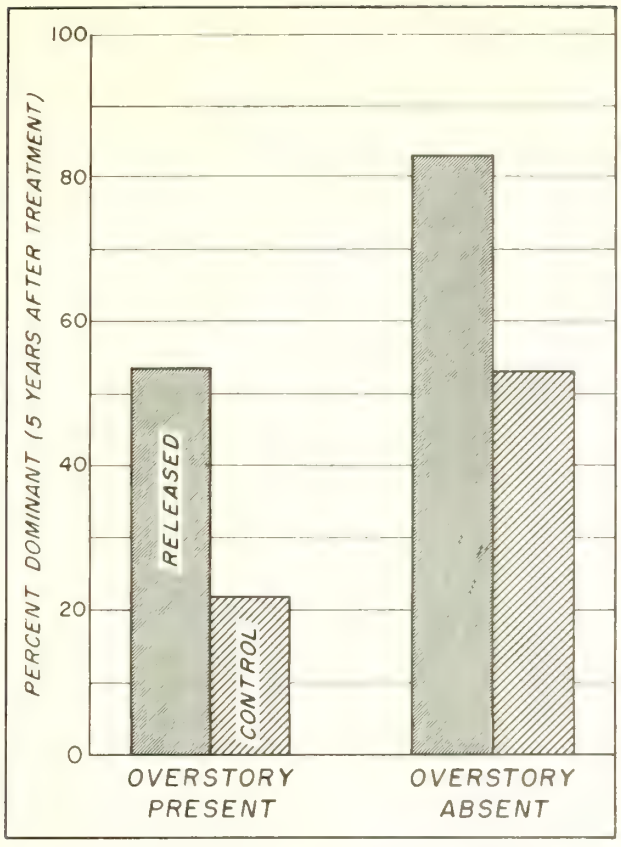

Figure 6. --Percentage of seedlings dominant 5 years after treatment, in relation to overstory conditions before treatment.

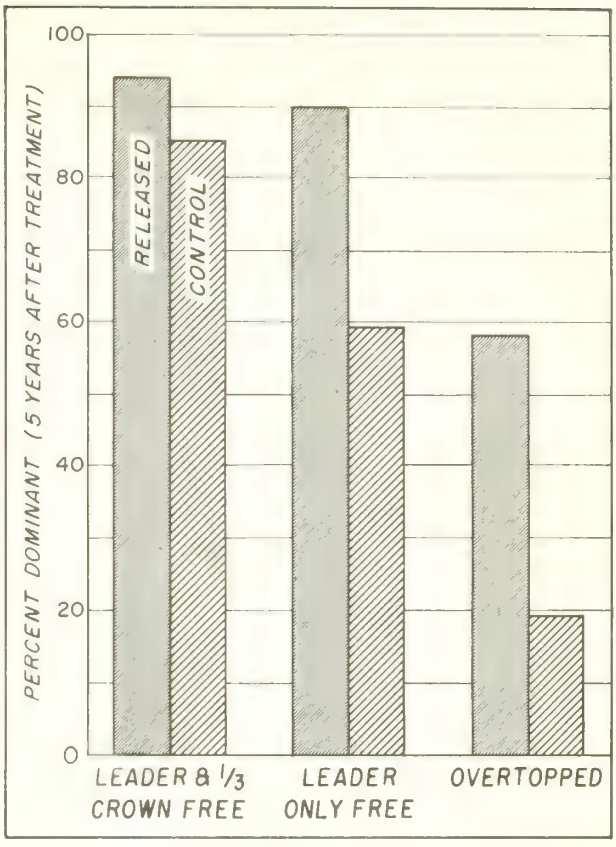

Figure 7. --Percentage of seedlings dominant 5 years after treatment, in relation to levels of low competition before treatment.

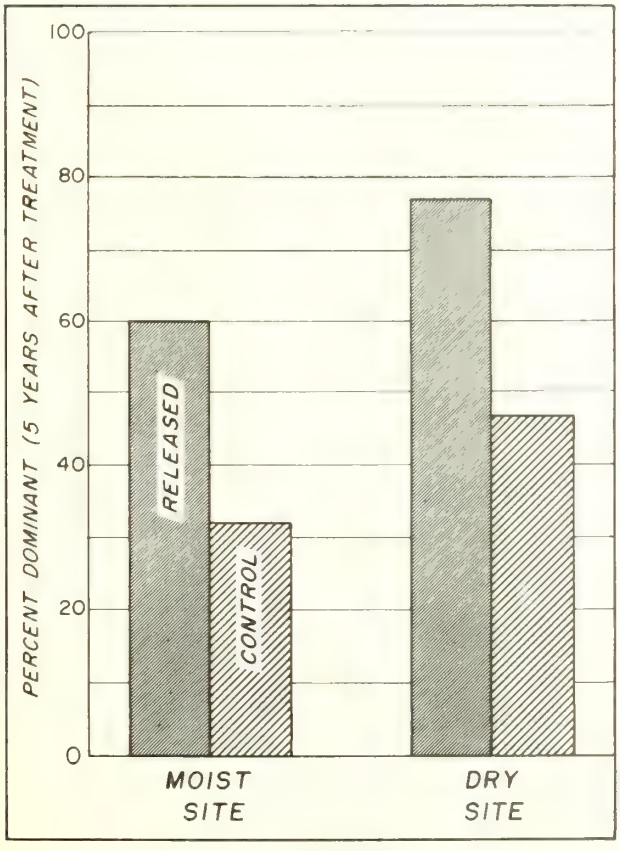

Figure 8. --Percentage of seedlings dominant 5 years after treatment, in relation to moisture conditions.

No association was found between frequency of attack and percentage dominant for either released or control seedlings. Tip moth attack therefore did not prevent seedlings from becoming dominant if other factors were favorable. Frequency of attack was high, 69.5 percent of all seedlings having been attacked once or more during the 3-year period.

A significantly higher percentage of released seedlings than control seedlings was attacked--74.5 percent compared to 63.9 percent. That behavior agrees with experience in other parts of the loblolly pine range (1). Overhead release of the seedlings apparently exposed them to more frequent attack.

This experience indicates that the tip moth usually is not a serious deterrent to the establishment of loblolly pine stands by natural regeneration. In plantations, however, attacks on some seedlings occasionally reach such an intensity that height growth is almost stopped.

Mortality

Reliable estimates of the stocking of potentially dominant seedlings cannot be made in the first year, not only because vegetative conditions are changing too rapidly but also because seedling mortality is high and largely due to factors other than competition. In the Bigwoods Experimental Forest, mortality among newly germinated seedlings was 7.5 percent in one year and 18.0 percent in another year, with a distinct tendency to be higher in lighter soil (4). After the first year, seedling prospects can be judged more reliably because mortality is much less and apparently is caused mainly by competition. Another study involving 2 year's records of 700 seedlings showed the following mortality rates among 2- to 5-year-old seedlings:

2-year-old seedlings (basis - 400)	1.1 percent
3-year-old seedlings (basis - 400)	1.7 percent
4-year-old seedlings (basis - 300)	0.4 percent
5-year-old seedlings (basis - 300)	0.1 percent

Heavy competition seems to favor other causes of mortality. Of the 445 seedlings chosen for the release study in 1947, 63 had died of natural causes by late 1952, five growing seasons later. Of these, 55 or 87.5 percent were overtopped by low competition although competition was considered the cause of death in only 32 of these cases. The causes of death are summarized in table 3.

HOW TO JUDGE SEEDLING PROSPECTS

The relations revealed by these studies are too complex to furnish a single, highly accurate criterion of future seedling dominance. However, the results suggest several simple, practical aids to judgment.

Table 3.--Causes of seedling mortality (during 5 years from 4 years to 9 years of age

Cause of death	Low competition	
	Leader free	Overtopped
	Number of seedlings	
Competition	2	32
Fusiform rust	0	2
Sawfly	5	13
Pine webworm	0	3
Rodents	0	2
Miscellaneous and unknown	1	3
Total	8	55

For seedlings among sprout clumps, a comparison of the height and past growth of the seedling and sprout clump will help to resolve doubtful cases. In loblolly pine seedlings the relation between current year's growth in feet (y) and previous year's growth in feet (x) was found to be:

$$y = 0.35 + 1.02x$$

This expression shows that, on the average, the height growth of pine seedlings during the first 5 years tends to increase somewhat in each succeeding year. The height growth of hardwood sprout clumps, on the other hand, tends to decrease during the same period. These tendencies are illustrated by the trends of height growth shown in figure 9.

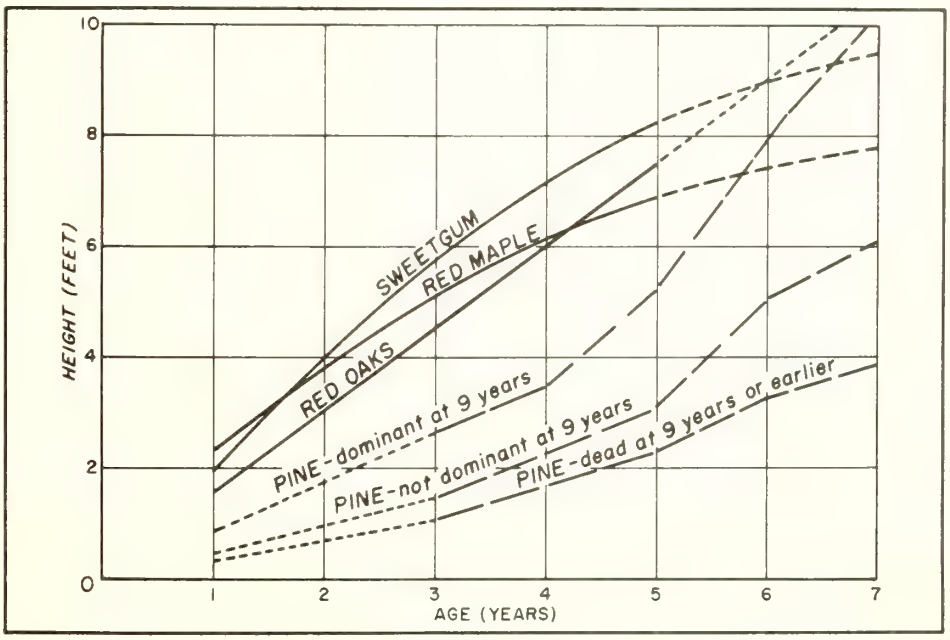

Figure 9.--Growth of hardwood sprout clumps and loblolly pine seedlings under average conditions.

Past growth of most hardwood species can be distinguished quite readily by the color and texture of the bark and the ring of scars left by the scales of the terminal bud at the beginning of growth. The several surges of growth made in one season by most loblolly pine seedlings may confuse some observers. Two or three branch whorls commonly occur within one year's height growth. The first internode usually is the longest and succeeding ones are progressively shorter. These sets of internodes frequently are so distinct that each year's growth can be distinguished on seedlings as much as 5 years old (fig. 10). The difference in appearance of needles on the main stem also helps to separate current from previous growth during late summer, when uncertainty is most likely. The older needles are duller, darker in color, and feel more brittle. Later in the fall these needles are cast and only the latest crop remains on the stem.

While such a comparison of prospective growth rates will help a careful observer estimate the stocking of potentially dominant seedlings, better results probably can be obtained by using the information on pine seedlings and hardwood sprout-clump behavior to enhance the reliability of two somewhat more objective criteria of eventual dominance. The growth of hardwood cover has slowed down to a low, constant rate by the third growing season (fig. 1); consequently, pine seedlings with their leaders free at that time or later should have a good chance of surpassing the hardwood competion. How good a chance is shown by the results of the release study (fig. 7), where 72 percent of seedlings with their leaders free at 4 years had become dominant at 9 years. In addition, 79 percent of the overtopped seedlings did not become dominant. Predictions based only on overtopping at 4 years would have been 74 percent correct. That level of accuracy, already fairly good, can be raised by modifying the predictions according to the comparative height, position, and growth of the seedlings and competing sprout clumps. For example, although a seedling is closely overtopped by a sprout clump, its past growth may show that it will easily grow through the single layer of hardwood foliage (fig. 11). On the other hand, a seedling with the leader free, beside a much taller sprout clump, may clearly have too far to grow before being engulfed by the expanding hardwood crown.

A second method is based on the height of seedlings at a given age. Seedlings were grouped into height classes at 3, 4, and 5 years of age and the percentage dominant at 9 years determined for each class at each of the earlier ages. Figure 12 illustrates the results of that procedure for 4-year-old seedlings. It is evident that at 4 years the critical height for eventual dominance is about 2 feet. If eventual dominance had been predicted for all seedlings taller and suppression for all those shorter than 2 feet at 4 years, 73 percent of the predictions would have been correct. For any other height the percentage of predictions correct would have been less. Critical heights were determined in the same fashion for 3- and 5-year-old seedlings, with the following results:

3-year-old seedlings - - - 1.5 feet (72 percent predictions correct)
4-year-old seedlings - - - 2.0 feet (73 percent predictions correct)
5-year-old seedlings - - - 4.0 feet (75 percent predictions correct)

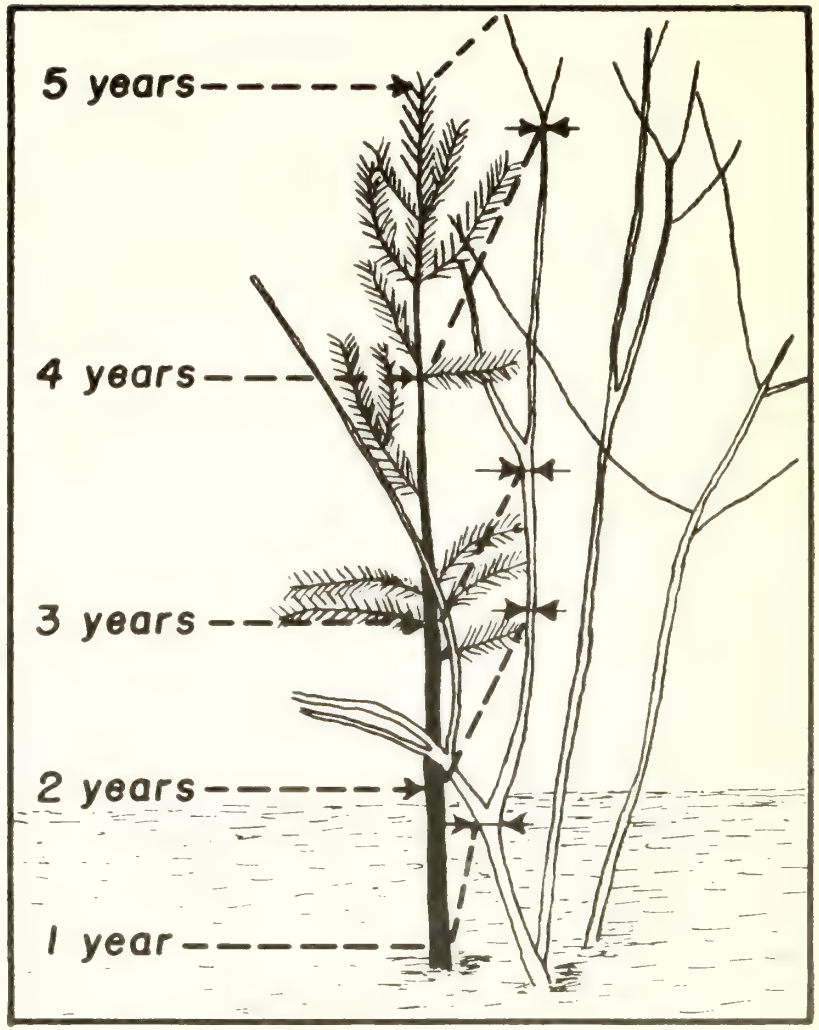

Figure 10.--Height and position of a loblolly pine seedling and the clump of maple sprouts through which it grew. Notice particularly the increasing rate of height growth of the pine seedling.

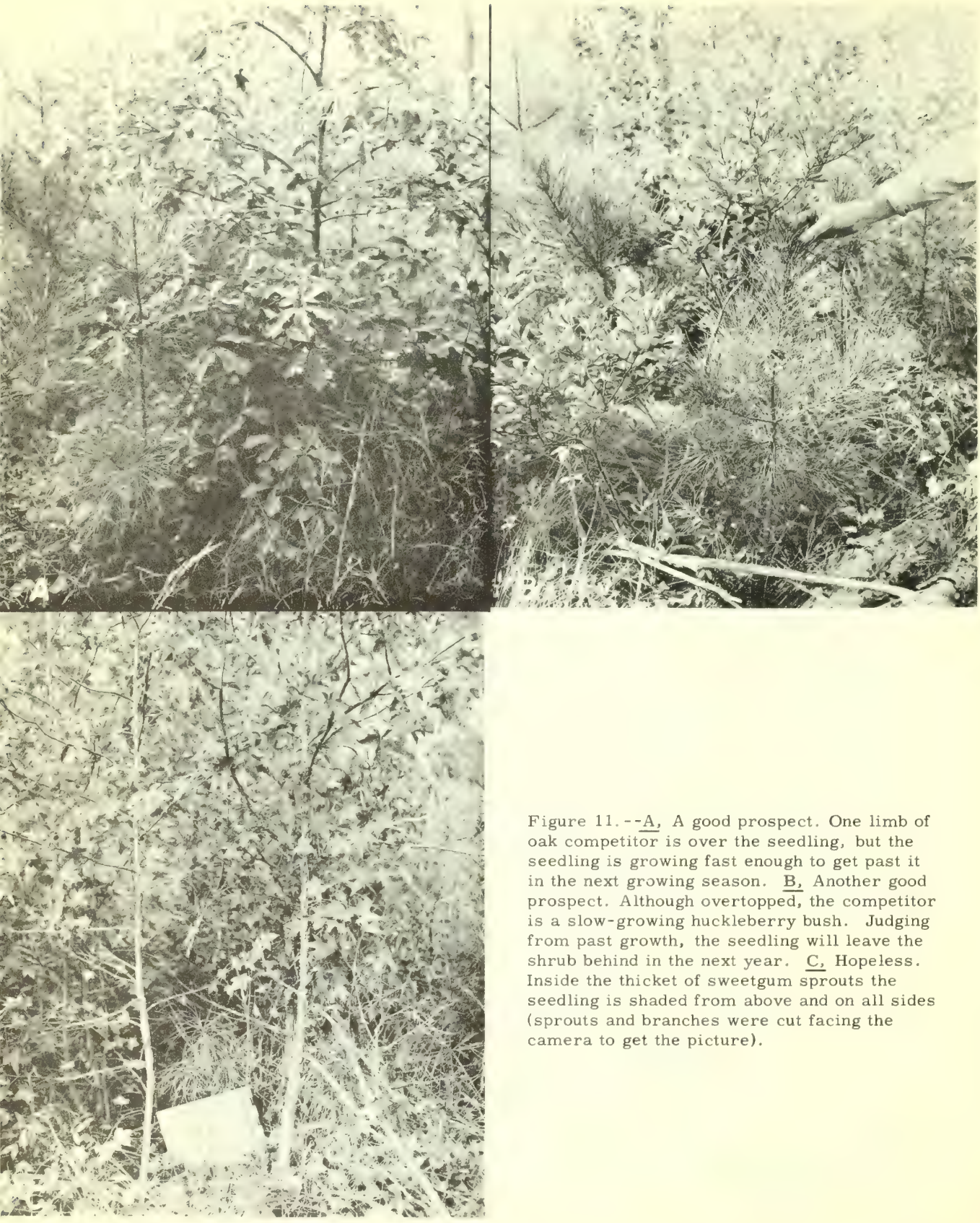

Figure 11.--A, A good prospect. One limb of oak competitor is over the seedling, but the seedling is growing fast enough to get past it in the next growing season. B, Another good prospect. Although overtopped, the competitor is a slow-growing huckleberry bush. Judging from past growth, the seedling will leave the shrub behind in the next year. C, Hopeless. Inside the thicket of sweetgum sprouts the seedling is shaded from above and on all sides (sprouts and branches were cut facing the camera to get the picture).

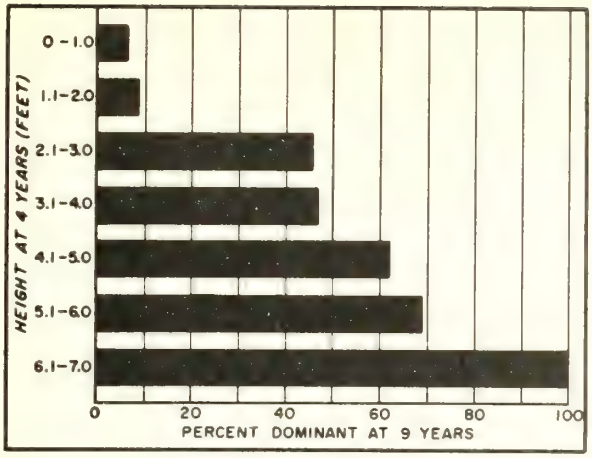

Figure 12.--Percentage of loblolly pine seedlings dominant at 9 years of age, according to height at 4 years of age. The percent dominant applies only to seedlings within the height range specified at left, and not to all seedlings above that height.

The two criteria of prospective dominance first described, comparative growth rates and free leaders in the third, or later, year of age, are applicable on any upland site since they are based on relative position of seedlings and hardwood competitors. The critical height method is applicable only on similar soils, however, because seedling height growth is influenced by soil characteristics. The seedlings that were the basis for that method were located on an area of well-drained sandy loam with a friable, sandy clay subsoil. Therefore, the method can probably be used in many areas in the southeastern coastal plain, where well-drained and moderately well-drained sandy loams are frequently encountered.

THE REPRODUCTION SURVEY

Estimates of reproduction are best made by the stocked quadrat method because it reflects not only the number of seedlings present but also their distribution. In that method small plots or quadrats are tallied as stocked if one or more seedlings of the desired species are present. The number of plots stocked divided by the total observed then gives the stocking percent. In loblolly pine a convenient and satisfactory plot size is one milacre (1/1000 acre). Plots are located in some predetermined fashion so that all parts of the area in question are sampled. For some purposes a random distribution may be needed but in practical work a systematic scheme is probably satisfactory in most cases. Reproduction surveys in the Bigwoods Experimental Forest utilize 100 milacre plots per 35-acre tract.

Opinions as to what constitutes adequate milacre stocking vary anywhere from 40 to 90 percent, that is, 400 to 900 well-distributed, free-to-grow seedlings per acre. To determine the need for further treatment, both the total present stocking and the stocking of potentially dominant seedlings must be estimated. If the total is below standard, release work would be inadequate, and some other treatment to establish more seedlings is needed. Only about 85 percent of the seedlings judged free to grow will actually become dominant.

The survey method can be modified in a number of ways to yield additional information for planning future work. One useful refinement is to record the kind of competition--residual hardwood trees or low brush--for plots stocked with a suppressed seedling. The tally would then show whether the pine seedlings need release from overhead competition or low competition or both.

If all plots are classified according to type of cover, whether seedlings are present or not, a rough estimate of the area under each type of cover can be obtained by applying the percentage of plots in each type to the whole area. If, in addition, the identity of individual plots is retained in the field record, the parts of the tract that need treatment can be located, since the direction of line and the plot interval are known.

If more precise estimates of types of hardwood cover are needed, they can be obtained by a line-intercept survey made while moving along the cruise lines, or by a further modification of the plot survey. In the line-intercept method, the observer simply records the distance traveled through each type of cover along the line. The percentage of the total length of line in each type applied to the total area yields an estimate of the acreage in each cover type. Again, by maintaining the identify of plot intervals, heavy concentrations of each cover type can be located. Another method of obtaining more precise estimates of the area occupied by residual hardwood trees is to tally hardwood stems on a larger plot at some of the milacre plot locations. Surveys utilizing thirty 1/10-acre plots per 35-acre tract have provided estimates of basal area of hardwoods accurate to within 10 percent of the actual basal area. The basal area in hardwood stems multiplied by 1.4 yields an estimate of the percent of total area occupied by hardwood crowns (3). And the number and diameter of the hardwood stems furnish a basis for estimating the cost of poisoning them with Ammate. McClay (2) found the following relation between hardwood stems and the time required to treat them with Ammate:

$$\frac{\text{man-hours}}{\text{per acre}} = 0.009 \text{ (sum of tree diameters)} - 0.005 \text{ (number of trees per acre)}$$

For stems under 6 inches d.b.h., one-third the basal area in square feet per acre will give a rough estimate of man-hours required for poisoning with Ammate.

SUMMARY

When natural regeneration is relied upon in the even-aged management of loblolly pine, the stocking of dominant and potentially dominant seedlings should be estimated as soon as possible to find out whether further treatment of the reproduction area is necessary. Study of the growth and development of pine seedlings and their hardwood competitors revealed relations too complex to furnish a single, highly accurate criterion of future seedling dominance. However, the following aids to judgment were developed:

1. Comparison of past height growth and relative positions of pine seedlings and competing sprout clumps. The annual height growth of pine seedlings, especially those likely to become dominant, tends to accelerate in succeeding years, while height growth rates of hardwood sprout clumps tend to decrease.

2. Overtopping in the third year or later. The growth of hardwood cover has slowed down to a low, constant rate by the third growing season. Pine seedlings not overtopped by that time have a good chance of becoming dominant. Seventy-two percent of seedlings with their leaders free at 4 years had become dominant at 9 years.

3. Seedling height at a given age. Seedlings that are 1.5 feet tall or taller at 3 years, 2.0 feet at 4 years, and 4.0 feet at 5 years of age, are likely to be dominant by 9 years of age. This method of judging prospective dominance is applicable only on a well-drained and moderately well-drained sandy loams in the coastal plain.

The stocking survey can be made to yield an estimate of pine stocking only, or can be modified to show in addition the kind and location of hardwood competition as a basis for planning any required cultural work.

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Agriculture-Asheville

Climatological Summaries for Selected Stations in and near the Southern Pine Region, 1921-1950

Compiled by
Harold W. Hocker, Jr.

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

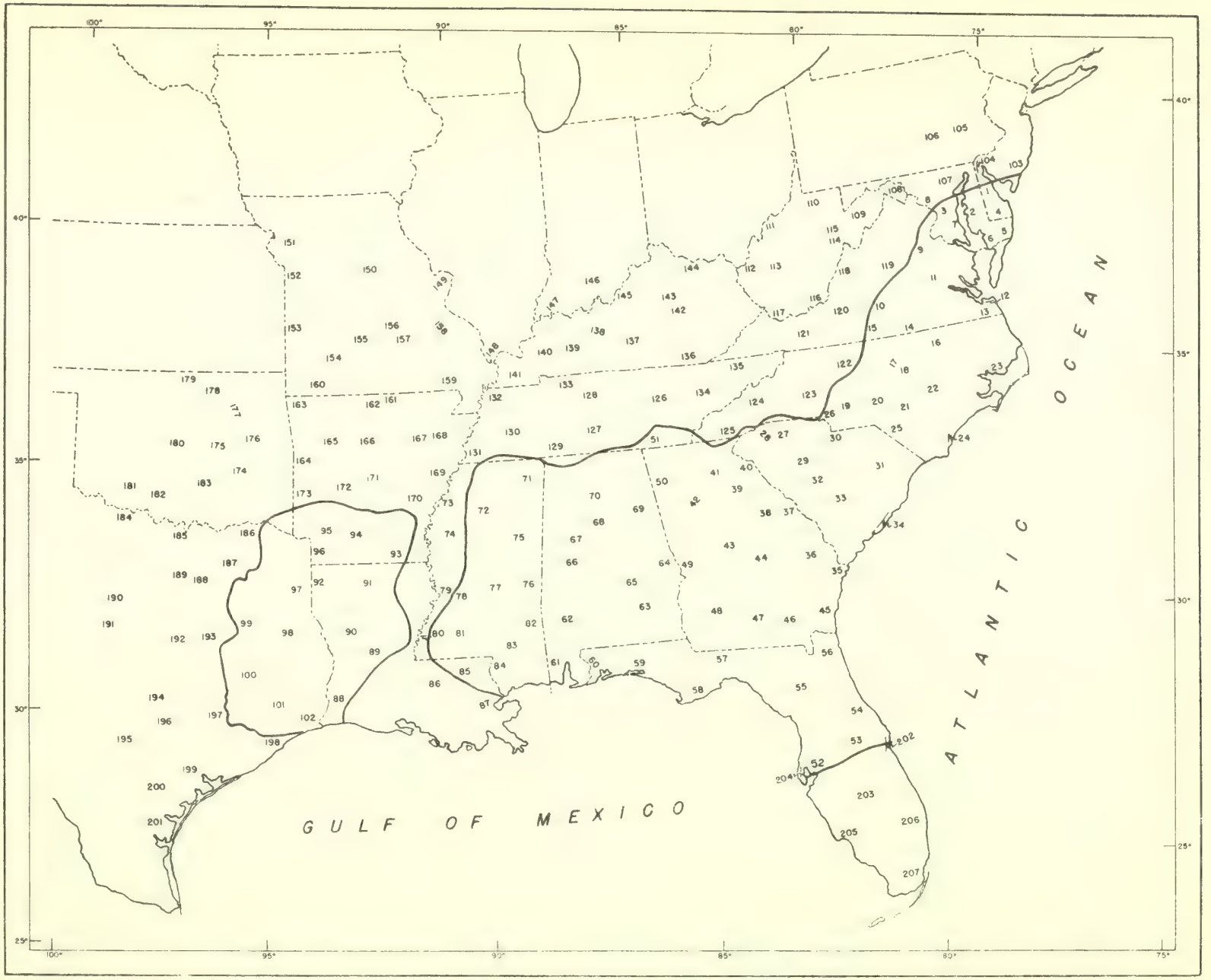

Figure 1.--Location of the selected stations.

CLIMATOLOGICAL SUMMARIES FOR SELECTED STATIONS IN AND NEAR THE SOUTHERN PINE REGION, 1921-1950

Compiled by
Harold W. Hocker, Jr.
School of Forestry, Duke University

The climatological data in the following tables were assembled and summarized in the course of a study of the relation between climate and the natural distribution of loblolly pine.[1/] This study was, in part, sponsored by the Southeastern Forest Experiment Station as a cooperative aid project with Duke University School of Forestry. The climatological data are now being made available in the hope that they may be useful to geneticists, silviculturists, ecologists, and others working in the southern pine region.

The climatological stations included were selected to represent equally the region of natural distribution of loblolly pine and an area outside the range of this species but adjacent to it. An attempt was made to obtain insofar as possible a uniform distribution of stations throughout these two regions. As a result, a major portion of the southern pine region is represented. The locations of these stations are plotted by number in figure 1; the names corresponding to these numbers are given in table 3. Of these stations, 83 are first-order U.S. Weather Bureau climatological stations, and 124 are cooperating stations.

The data are based upon U.S. Weather Bureau records for the period 1921 through 1950. In a majority of cases, the averages are based upon records which are complete for the 30-year period, and in no instance is the average based upon a record of fewer than 25 years. The use of records all made within a given 30-year period, it was believed, would take into account any short-term climatic trends and would, at the same time, insure that there was a true basis for statistical comparison of the data for all stations.

Maximum, minimum, and average temperatures and the total monthly precipitation data for the 83 first-order stations were obtained from published "normals" calculated for the period 1921 through 1950.[2/] Where possible, all basic data for cooperating stations and frost and precipitation frequency data for all first-order stations were obtained from U.S. Weather Bureau monthly and annual summaries published during the period 1921-1950. These data, with the exception of frost occurrence, were recorded for each month for which the data were available within the period. In instances where at least a 25-year record within the period 1921-1950 could not be obtained for any climatic factor from the published records, the station observer's original records [3/] were consulted, and a record of 25 years or more was thus completed. From these basic data, average monthly values were calculated for each factor; annual values were then determined from the twelve monthly averages.

The author wishes to acknowledge the many courtesies extended by the staff of the National Weather Records Center, Asheville, N.C., in making available climatological records. Grateful acknowledgement is also made to Dr. C. F. Korstian, of Duke University School of Forestry, and to Dr. Carl Ostrom, of the Forest Experiment Station staff, for their interest and cooperation.

1/ Doctor of Forestry dissertation, Duke University School of Forestry.

2/ U.S. Department of Commerce, Weather Bureau. Monthly normal temperatures, precipitation, and degree days (1921-50). Government Printing Office, Washington, D.C. 1953.

3/ On file at the National Weather Records Center, Asheville, North Carolina

TEMPERATURE DATA FOR SELECTED STATIONS IN AND NEAR THE SOUTHERN PINE REGION

Table 1.

STATION	AVERAGE MONTHLY TEMPERATURE													AVERAGE MAXIMUM MONTHLY TEMPERATURE												AVERAGE MINIMUM MONTHLY TEMPERATURE											
	January	February	March	April	May	June	July	August	September	October	November	December	Annual	January	February	March	April	May	June	July	August	September	October	November	December	Annual	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
ALABAMA																																					
Anniston	45.8	47.9	53.7	61.9	69.8	78.0	79.7	79.1	74.3	63.6	50.4	45.2	62.5	56.6	59.7	65.8	74.9	83.0	90.5	91.2	90.4	86.6	76.5	61.8	55.5	74.4	34.9	36.1	41.5	48.9	56.6	65.5	68.2	67.7	62.0	50.6	38.9	34.9	50.5
Auburn	49.4	51.5	56.7	64.3	71.9	78.9	80.3	79.9	76.6	67.1	55.8	49.8	65.2	59.7	62.3	67.7	76.1	83.7	90.4	90.9	90.4	87.8	79.2	67.3	60.0	76.3	39.1	40.6	45.2	52.6	60.1	67.5	69.7	69.3	65.5	54.9	44.6	39.5	54.1
Birmingham	45.2	47.7	53.8	61.9	69.5	77.4	79.6	79.1	74.8	63.7	52.0	45.7	62.5	55.5	58.3	65.3	73.9	81.5	88.7	90.2	89.9	86.4	76.8	64.0	56.2	73.9	34.9	37.1	42.3	49.8	57.5	66.1	69.0	68.2	63.1	50.6	40.0	35.1	51.1
Greensboro	49.1	51.3	57.1	65.2	72.8	80.0	81.5	81.3	77.6	67.5	56 2	49.4	65.8	59.2	61.7	68.2	76.3	83.6	90.4	91.3	91.6	88.3	79.4	67.7	59.7	76.5	39.0	40.7	46.0	54.0	61.9	69.7	71.8	71.2	67.0	55.6	44.8	39.6	55.1
Mobile	52.7	55.0	59.5	66.7	73.4	79.6	80.7	80.8	77.7	69.1	58.7	53.5	67.3	62.2	64.7	69.1	76.3	82.8	88.5	89.4	89.7	86.6	79.4	69.0	63.0	76.7	43.2	45.2	49.9	57.0	64.0	70.6	72.0	71.9	68.7	58.8	48.3	43.9	57.8
Montgomery	49.2	51.6	57.1	64.7	72.5	79.6	81.2	80.9	77.1	66.4	55 2	49.4	65.4	59.7	62.5	68.6	76.6	84.2	90.5	91.3	91.0	88.0	78.9	67.3	60.1	76.6	38.7	40.6	45.5	52.7	60.7	68.7	71.0	70.7	66.2	53.9	43.1	38.6	54.2
St. Bernard	43.4	45.8	52.2	60.7	68.3	76.2	78.6	77.8	73.4	62.2	50 6	44.0	61.1	54.3	57.3	64.8	74.2	81.3	88.8	90.5	89.9	85.9	76.0	63.0	54.5	73.4	32.7	34.2	39.6	47.6	55.3	63.7	66.8	65.8	60.8	48.4	38.3	32.7	48.8
Thomasville	50.3	52.0	57.8	65.4	72.6	79.5	80.8	80.6	76.8	67.0	56.5	50.9	65.9	61.1	61.2	69.2	77.6	84.6	91.3	92.1	92.0	88.4	79.8	68.3	61.4	77.3	39.7	40.9	46.7	53.1	60.7	67.7	69.6	69.2	65.3	54.3	44.8	40.1	54.3
Troy	50.9	53.1	58.3	65.8	73.0	79.5	80.5	80.3	76.8	67.1	56.7	51.5	66.1	60.9	63.7	69.5	77.5	84.7	90 9	91.0	90.9	88.1	78.9	68.1	61.5	77.1	40.8	42.6	47.1	54.2	61.4	68.2	70.2	69.7	65.9	55.5	45.3	41.3	55.2
Tuscaloosa	47.0	49.5	55.7	64.0	71.8	79.8	81.7	81.2	76.6	65.5	54.1	47.6	64.5	57.7	60.5	67.4	76.3	83.8	91.4	92.7	92.5	88.5	78.8	66.4	58.1	76.2	36.9	38.6	43.7	52.1	60.2	68.5	70.8	69.9	65.1	52.7	42.4	37.2	53.2
ARKANSAS																																					
Bee Branch	39.8	43.4	50.7	60.8	67.8	76.8	80.9	80.2	74 0	62.8	49.8	41.9	60.7	50.5	55.1	62.9	73.4	80.1	89.2	94.0	93.6	87.8	76.7	61.8	52.4	73.1	28.9	31.7	38.4	48.2	55.6	64.5	68.0	67.0	60.7	48.9	37.8	31.1	48.4
Camden	44.4	48.0	54.7	63.9	70.8	79.1	81.9	81.8	75.8	64.8	52.8	46.1	63.7	56.4	59.9	67.6	76.5	83.1	90.9	94.0	95.0	89.5	79.8	66.7	57.7	76.4	33.1	35.9	41.8	51.3	58.6	67.1	69.9	68.9	62.5	49.9	39.4	34.1	51.0
Fort Smith	40.0	44.6	52.3	62.6	69.6	78.3	82.3	82.1	75.0	63.9	50.5	42.5	62.0	50.6	55.4	63.8	74.1	80.8	89.7	94.2	94.2	87.1	76.4	61.9	53.0	73.4	29.4	33.8	40.7	51.0	58.3	66.9	70.4	70.0	62.9	51.3	39.0	32.0	50.5
Gravette	36.7	40.6	48.0	58.5	65.5	74.4	79.0	78.8	71.6	60.9	47.7	39.7	58.5	48.3	52.1	60.3	70.6	77.2	85.7	91.6	91.7	84.2	73.8	59.7	50.5	70.5	25.6	28.7	35.7	46.4	54.1	63.2	66.5	66.4	59.2	47.8	35.9	28.7	46.5
Hope	44.1	47.7	54 5	63.8	70.8	79.2	82.3	82.6	76.3	65.4	52.9	46.4	63.8	55.1	58.6	66.6	75.9	82.6	91.1	94.6	95.4	89.3	79.5	65.2	57.6	76.0	33.2	36.5	42.7	51.5	58.9	67.3	70.1	69.7	63.3	51.4	40.5	34.8	51.7
Hot Springs	43.8	47.1	54.0	63.7	70 5	78.9	82.4	82.5	76.0	65.7	52.6	45.3	63.5	53.1	58.2	65.6	75.8	82.3	90.4	94.4	95.1	88.2	78.2	63.3	54.9	75.0	33.9	36.8	42.5	51.6	58.7	67.4	70.8	70.3	64.2	53.4	42.0	35.6	52.3
Little Rock	41.8	45.6	52.8	62.5	69.8	78.5	81 9	81.3	74 8	64.1	51.5	43.9	62.4	51.1	55 4	63.4	73.4	80.5	89.1	92.7	92.4	86.4	76.5	62.4	53.5	73.1	32.4	35.7	42.2	51.6	59.0	67.9	71.1	70.2	63.1	51.7	40.5	34.3	51.6
Lutherville	40.3	44.0	51.2	61.1	68.2	76.5	80.6	80.9	74.3	63.6	50.7	42.5	61.2	50.2	54.3	62.3	72.3	78.7	87.1	92.4	92.8	86.4	75.7	61.6	52.1	72.2	30.4	33.4	40.0	50.0	57.4	65.9	69.3	68.9	62.7	51.6	39.8	32.7	50.2
Mammoth Spring	38.0	40.8	49.4	59.7	66.6	75.3	79 2	78.4	71.5	60.0	47.9	39.8	58.9	49.4	53.0	62.4	72.7	79.2	87.5	91.8	91.2	84.6	74.6	61.3	51.6	71.6	26.6	28.5	36.4	46.5	53.8	63.2	66.7	65.8	58.5	45.7	35.0	27.9	46.2
Mariana	42.8	46.1	53.6	62.8	70.3	78.5	81.0	80.1	74.4	63.7	51.9	44.5	62.5	53.0	56.1	64.7	73.8	81.3	89.3	92.0	91.4	85.7	76.3	63.8	54.4	73.5	33.0	35.8	42.5	51.9	59.4	70.2	70.2	69.3	63.5	51.1	40.6	34.0	51.8
Marked Tree	39.1	42.2	50.0	60.8	69.0	77.7	80.6	79.5	73.1	61.8	48.8	40.7	60.3	49.3	52.0	61.6	71.8	80.7	88.8	92.1	91.4	85.6	75.3	60.7	50.5	71.7	28.9	31.4	39.0	49.5	57.9	66.4	69.1	68.4	61.1	47.9	37.0	30.4	48.9
Mena	41.7	45.5	52.5	62.1	68.7	76.9	80.5	80.8	74.3	63.9	51.4	43.7	61.8	51.4	55.7	63.8	73.7	79.9	88.1	92.8	93.4	86.7	76.0	62.2	53.1	73.1	32.0	34.9	41.3	50.4	57.5	65.7	68.6	68.6	62.3	52.0	40.8	34.1	50.7
Mountain Home	38.2	41.8	49.6	59.3	66.6	75.3	79.5	78.6	71.9	61.1	48.5	40.4	59 2	49.8	53.9	62.3	72.3	79.3	87.7	92.5	92.1	85.7	75.7	61.5	51.8	72.1	26.5	29.8	36.8	46.4	53.9	63.0	66.6	65.4	58.3	46.5	35.7	28.7	46.5
Newport	41.0	44.7	52.6	62.4	69.9	78.6	81.9	81.1	74.8	63.7	51.1	43.1	62.1	50.5	55.2	63.8	73.8	81.4	90.1	93.8	93.5	87.6	77.1	62.7	52.9	73.5	31.3	34.6	41.4	50.9	58.4	67.1	70.1	69.0	62.3	50.4	39.6	33.1	50.7
Portland	46.9	50.0	56.6	65.1	71.9	79.6	81.8	81.4	76.0	65.4	54.7	48.4	64.8	57.4	60.8	68.5	77.1	83.5	91.3	93.4	93.7	88.4	78.9	67.2	59.1	76.6	36.2	39.0	44.7	53.0	60.2	67.8	70.4	69.4	63.9	52.0	42.5	37.7	53.1
Stuttgart	43.4	46.6	54.1	62.9	70.1	78.6	81.9	81.4	75.6	64.7	52.5	45.3	63.1	53.3	56.7	64.9	74.1	81.1	89.5	93.6	93.4	88.0	78.1	63.4	55.3	74.3	33.5	36.3	42.7	51.7	59.2	67.7	70.8	69.7	63.5	51.4	40.8	35.2	51.9
Texarkana	45.9	49.5	56.0	65.0	71.9	79.9	82.9	82.7	77.2	67.0	54.8	48.0	65.1	56.3	60.4	67.7	76.7	83.1	91.0	94.6	94.5	89.7	80.2	66.7	58.4	76.6	35.5	38.6	44.3	53.3	60.6	68.7	71.1	70.9	64.7	53.7	42.9	37.5	53.5
DELAWARE																																					
Dover	36.0	36.3	44.6	53.1	63.6	72.7	76.6	74.7	69.2	57.8	47.9	37.7	55.9	44.7	45.4	54.9	64.0	74.8	83.5	86.7	84.9	79.4	68.7	57.8	46.1	65.9	27.3	27.1	34.3	42.1	52.5	62.0	66.6	64.8	59.1	47.3	38.1	28.9	45.8
Millsboro	37.4	37.7	45.2	53.1	63.5	72.6	76.3	74.7	69.4	57.9	48.1	38.5	56.2	47.5	48.4	56.5	65.1	75.6	84.0	87.0	85.7	80.4	69.9	59.3	48.6	67.3	27.6	27.3	34.0	41.2	51.4	61.3	66.0	64.2	58.5	46.1	37.0	27.5	45.2
Wilmington	33.3	33.7	42.5	51.8	62.8	71.8	75.9	73.8	68.0	56.2	45.5	35.1	54.2	41.8	42.8	53.0	63.2	74.6	83.1	86.7	84.6	78.8	67.2	55.3	43.9	64.6	24.7	24.6	32.0	40.4	51.0	60.4	65.0	62.9	57.1	45.2	35.7	26.2	43.8
FLORIDA																																					
Apalachicola	55.2	56.9	60.9	67.5	74.4	79.9	81.3	81.3	78.9	71.0	61.4	56.3	68.8	62.2	64.0	67.8	74.2	81.1	86.2	87.4	87.3	84.7	78.2	69.0	63.7	75.5	48.1	49.7	54.0	60.8	67.6	73.5	75.1	75.2	73.0	63.8	53.7	48.9	62.0
Avon Park	64.1	65.3	68.6	72.9	77.2	80.8	81.8	82.2	80.8	75.8	68.8	65.0	73.6	75.5	77.5	80.8	85.0	89.1	91.3	91.7	92.2	90.3	85.5	79.5	76.2	84.6	53.1	53.2	56.2	60.9	65.4	70.3	71.9	72.3	71.5	66.1	58.3	53.5	62.7
Daytona Beach	59.5	60.5	63.7	69.0	74.4	79.1	80.8	80.9	79.4	73.4	65.1	60.5	70.5	69.3	71.0	74.4	79.6	84.7	88.6	89.8	89.7	87.2	81.6	74.2	69.7	80.0	49.6	49.9	52.9	58.3	64.0	69.6	71.7	72.1	71.5	65.2	55.9	51.3	61.0
De Funiak Springs	54.3	56.2	61.0	68.1	75.3	80.4	81.3	81.3	78.3	69.7	59.5	54.7	68.3	64.9	67.7	72.6	80.0	86.8	91.2	91.3	91.7	88.8	81.4	71.2	65.1	79.4	43.4	45.1	49.5	56.2	63.4	69.6	71.2	71.0	68.0	58.0	47.9	44.0	57.3
Fort Myers	64.6	65.6	68.6	73.0	76.9	80.6	82.0	82.5	81.3	76.3	69.2	65.6	73.9	75.2	76.6	79.6	84.1	87.7	90.0	90.5	91.0	89.5	85.0	79.1	76.0	83.7	53.9	54.6	57.5	61.8	66.1	71.2	73.4	74.0	73.1	67.5	59.3	55.1	64.0
Gainesville	58.4	60.0	64.0	69.7	75.4	79.8	80.7	80.9	79.2	72.1	63.6	58.8	70.2	69.2	71.5	75.6	81.4	87.3	90.2	90.3	90.8	88.9	82.8	74.9	69.6	81.0	47.6	48.8	52.4	58.0	63.5	69.4	70.9	71.1	69.5	61.4	52.5	47.6	59.4
Jacksonville	55.9	57.5	62.3	68.4	74.9	80.3	82.1	81.8	79.2	70.9	61.6	56.4	69.3	66.3	68.2	73.2	79.0	85.2	90.0	91.4	90.7	87.5	80.0	71.8	66.7	79.2	45.4	46.7	51.4	57.8	64.5	70.6	72.7	72.9	70.8	61.7	51.4	46.0	59.3
Melbourne	62.6	64.1	67.0	71.2	75.2	79.1	81.1	81.5	80.3	75.1	67.9	64.2	72.4	71.3	73.4	76.3	79.9	84.0	87.5	89.1	89.5	87.2	82.2	76.6	72.9	80.8	53.8	54.8	57.6	62.5	66.3	70.7	73.0	73.5	73.3	68.0	59.2	55.4	64.0
Miami	68.5	68.7	70.8	74.1	77.1	80.3	81.6	82.1	81.0	77.6	72.3	69.5	75.3	74.4	74.9	76.7	79.5	82.3	85.4	86.8	87.2	86.0	82.6	77.7	75.4	80.7	62.6	62.5	64.8	68.6	71.9	75.2	76.4	76.9	76.0	72.6	66.8	63.6	69.8
Orlando	61.9	63.2	66.7	71.6	76.5	80.8	82.1	82.5	80.7	74.7	66.8	62.7	72.5	73.0	74.8	78.1	83.0	87.7	90.7	91.4	91.8	89.5	84.5	77.7	73.8	83.0	50.7	51.6	55.3	60.2	65.3	70.9	72.7	73.1	71.9	64.9	55.9	51.6	62.0
Pensacola	54.0	56.0	60.2	67.0	73.8	79.6	81.0	81.2	78.3	70.3	60.2	55.1	68.0	61.1	63.1	66.9	73.2	79.8	85.5	86.9	87.4	84.6	77.7	68.0	62.4	74.7	46.9	48.8	53.4	60.8	67.7	73.7	75.0	74.9	72.0	62.8	52.4	47.7	61.3
St. Petersburg	64.0	65.2	68.4	73.5	78.2	81.8	82.7	83.2	81.9	76.7	69.2	65.0	74.1	72.2	73.7	76.7	81.6	86.3	89.4	90.0	90.6	89.1	84.0	77.3	73.0	82.0	55.8	57.0	60.1	65.3	70.1	74.2	75.3	75.8	74.8	69.3	61.2	56.7	66.3
Tallahassee	53.6	55.6	60.5	67.2	74.2	79.7	81.0	80.9	78.0	68.8	58.8	54.1	67.7	65.2	67.7	72.5	79.6	86.4	90.6	91.0	90.9	88.4	80.5	71.0	65.7	79.1	42.0	43.4	48.5	54.8	62.0	68.7	71.0	70.8	67.5	57.0	46.6	42.4	56.2
Tampa	61.5	62.9	66.0	71.5	76.5	80.4	81.7	82.0	80.5	74.6	66.7	62.7	72.3	70.8	72.3	75.4	81.1	86.0	88.9	89.5	90.1	88.3	83.4	76.2	72.1	81.2	52.1	53.4	56.6	61.8	67.0	71.9	73.8	73.9	72.6	65.8	57.2	53.2	63.3
West Palm Beach	67.0	67.7	70.0	73.8	77.1	80.6	82.0	82.2	81.2	77.6	71.7	68.7	75.0	75.4	76.9	78.9	82.7	85.9	88.6	89.9	90.1	88.4	84.6	79.6	77.1	83.2	58.6	58.4	61.1	64.9	68.3	72.6	74.0	74.3	74.0	70.6	63.8	60.2	66.7
GEORGIA																																					
Alapaha	53.0	54.9	59.9	67.0	74.0	80.0	81.4	81.0	77.9	68.5	58.6	53.2	67.5	64.4	66.8	71.8	79.4	86.1	91.3	91.9	91.5	88.8	80.6	70.9	64.7	79.0	41.6	43.1	48.1	54.6	62.0	68.8	70.9	70.4	67.0	56.3	46.3	41.7	55.9
Albany	51.4	53.5	59.4	67.0	74.9	81.3	82.5	81.9	78.7	68.6	57.4	51.7	67.4	62.4	64.9	71.2	79.3	87.0	92.4	93.0	92.4	89.5	80.6	69.6	62.7	78.8	40.3	42.1	47.5	54.6	62.8	70.1	71.9	71.4	67.8	56.5	45.2	40.6	55.9
Athens	44.7	46.6	52.7	61.7	70.4	78.9	80.8	79.7	75.2	63.9	52.0	45.2	62.7	54.6	57.3	64.5	74.0	82.7	90.9	92.4	90.9	87.0	76.3	63.4	54.9	74.1	34.8	35.9	40.8	49.3	58.0	66.8	69.1	68.4	63.4	51.4	40.6	35.5	51.2
Atlanta	44.6	46.7	52.7	61.7	70.0	77.7	79.5	78.6	74.4	63.4	51.9	45.2	62.2	53.3	56.2	63.3	72.8	80.8	88.2	89.4	88.5	84.3	73.8	61.6	53.7	72.2	35.9	37.2	42.0	50.6	59.1	67.1	69.6	68.7	64.4	52.9	42.2	36.6	52.2
Augusta	48.7	50.5	56.5	64.9	72.9	80.0	81.5	80.7	77.0	66.7	55.9	49.3	65.4	58.3	60.6	66.8	76.4	84.1	90.6	91.5	90.6	86.9	77.7	66.4	58.9	75.7	39.1	40.4	46.1	53.4	61.7	69.3	71.4	70.8	67.0	55.6	45.4	39.7	55.0
Brooklet	51.7	53.6	59.3	66.9	74.1	80.2	81.8	81.0	77.3	68.0	58.0	51.1	66.9	62.7	64.8	71.6	80.1	87.0	92.1	93.0	92.0	88.2	80.1	70.0	62.1	78.6	41.3	42.1	47.3	53.8	61.3	68.3	70.7	69.9	66.3	56.3	46.0	40.1	55.3
Brunswick	55.4	56.9	61.6	68.4	75.0	80.6	82.1	82.0	79.1	70.9	61.7	55.9	69.1	65.1	66.8	71.8	78.4	84.5	89.7	90.9	90.7	87.5	79.5	71.2	65.3	78.5	45.6	47.0	51.5	58.4	65.5	71.5	73.2	73.3	71.1	62.2	52.3	46.1	59.8
Columbus	47.4	49.6	54.7	63.4	72.0	79.0	80.9	80.2	76.2	65.8	54.3	47.6	64.2	58.1	61.1	67.1	75.9	84.2	90.4	91.0	90.3	86.7	77.8	66.8	58.3	75.6	36.7	38.1	42.2	50.9	59.8	67.6	70.7	70.1	65.7	53.7	41.8	36.8	52.8
Dublin	50.4	52.3	58.1	65.5	72.9	79.8	81.3	80.7	77.0	66.5	56.4	50.4	65.9	61.8	64.1	70.6	78.6	85.5	91.7	92.2	92.0	88.9	79.8	69.5	61.9	78.1	38.8	40.5	45.7	52.4	60.2	67.9	70.2	69.4	65.2	53.2	43.4	38.5	53.8
Gainesville	43.1	45.1	51.2	59.6	67.4	75.2	77.4	76.6	72.0	61.0	50.4	43.9	60.2	52.9	55.7	62.8	71.8	79.5	86.9	88.3	87.4	83.2	73.3	61.9	53.8	71.5	33.3	34.1	39.6	47.4	55.3	63.5	66.5	65.9	61.0	48.6	38.8	33.9	49.0
Hartwell	44.7	46.8	52.9	61.3	69.6	77.6	79.6	78.7	74.4	63.3	52.0	45.3	62.2	55.3	58.3	65.2	74.2	82.3	89.7	91.0	89.7	86.1	76.0	64.0	56.1	74.0	34.0	35.4	40.6	48.4	56.9	65.5	68.4	67.6	62.7	50.4	39.5	34.4	50.3
Macon	49.5	51.5	57.8	65.7	73.6	80.9	82.4	81.7	77.5	66.6	56.0	49.7	66.1	60.4	62.7	69.7	78.0	85.8	92.5	93.3	92.5	88.5	79.0	67.8	60.6	77.6	38.6	40.3	45.8	53.3	61.4	69.2	71.5	70.8	66.4	54.1	44.1	38.8	54.5
Rome	42.7	45.0	51.7	60.5	69.2	77.4	80.0	78.8	74.2	62.2	50.5	43.3	61.3	53.6	56.6	64.6	74.3	82.8	90.4	92.2	91.4	87.3	76.5	63.3	54.3	73.9	31.8	33.4	38.8	46.7	55.6	64.3	67.7	66.2	61.0	47.9	37.6	32.2	48.6
Savannah	52.1	53.9	59.0	65.8	72.9	79.7	81.4	80.9	77.3	67.7	58.1	52.4	66.8	62.2	64.0	69.4	76.5	83.2	89.3	90.5	89.7	85.9	77.6	68.6	62.5	76.6	42.0	43.8	48.5	55.1	62.6	70.0	72.2	72.1	68.6	57.8	47.6	42.3	56.9

TEMPERATURE DATA FOR SELECTED STATIONS IN AND NEAR THE SOUTHERN PINE REGION

Table 1. (Continued)

STATION	AVERAGE MONTHLY TEMPERATURE													AVERAGE MAXIMUM MONTHLY TEMPERATURE												AVERAGE MINIMUM MONTHLY TEMPERATURE											
	January	February	March	April	May	June	July	August	September	October	November	December	Annual	January	February	March	April	May	June	July	August	September	October	November	December	Annual	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
GEORGIA (Cont'd.)																																				
Warrenton	47.8	49.6	55.7	63.7	71.4	78.7	80.4	79.5	75.5	64.8	54.4	48.1	64.1	58.0	60.4	67.0	75.8	83.3	89.7	90.7	89.8	85.5	76.2	65.5	57.9	75.0	37.5	38.5	43.7	51.5	59.6	67.6	70.1	69.6	65.1	53.5	43.2	37.4	53.1
Waycross	54.9	56.5	61.4	67.8	74.4	80.2	81.7	81.6	78.5	69.5	60.0	54.7	68.4	67.4	69.1	74.0	80.7	87.1	91.7	92.5	92.7	89.5	82.0	73.5	66.9	80.6	42.4	44.1	48.7	54.9	61.6	68.6	70.9	70.6	67.6	57.1	46.6	41.9	56.3
KENTUCKY																																				
Berea College	37.3	39.2	46.9	56.7	65.0	73.3	76.4	75.1	70.0	58.9	46.9	39.0	57.1	46.7	49.0	58.8	68.5	76.8	85.0	87.8	86.5	81.9	70.9	57.2	47.9	68.1	27.9	29.1	35.9	44.9	53.3	62.0	65.0	64.0	58.5	46.8	36.6	29.9	46.2
Greensburg	37.1	39.5	47.2	56.5	64.6	73.6	76.8	75.5	69.8	57.8	46.5	38.7	57.0	47.8	50.4	59.7	70.1	77.9	86.2	89.6	88.2	83.1	72.1	58.8	49.0	69.4	26.4	28.3	34.9	43.0	51.3	61.0	64.3	62.9	56.7	43.6	34.4	28.4	44.6
Greenville	36.9	39.5	47.6	57.2	65.2	74.3	77.6	76.4	70.6	59.5	47.2	38.9	57.6	47.2	50.0	58.7	69.6	77.8	86.6	89.4	89.2	84.1	73.7	59.1	48.9	69.5	26.6	28.8	35.7	44.9	52.6	61.7	65.1	63.6	57.3	45.4	35.6	28.6	45.5
Leitchfield	36.7	38.9	47.1	56.8	65.3	74.0	77.5	76.2	70.6	59.4	47.1	38.5	57.3	45.6	48.4	57.8	68.2	76.8	85.1	88.8	87.5	82.3	71.4	57.1	47.2	68.0	27.7	29.4	36.4	45.4	54.0	63.0	66.3	65.0	59.1	47.4	37.1	29.6	46.7
Lexington	32.5	34.5	42.4	52.9	62.6	72.2	75.7	74.4	68.9	57.3	43.8	34.9	54.4	40.5	42.7	51.8	63.0	73.1	82.6	86.2	85.2	80.2	68.5	53.1	42.9	64.2	24.5	26.3	33.0	42.8	52.1	61.8	65.2	63.6	57.5	46.0	34.5	26.8	44.5
Louisville	34.9	37.2	45.6	56.0	65.3	74.2	77.9	76.1	70.2	58.6	45.7	36.9	56.5	43.6	46.3	56.0	67.0	76.6	85.2	89.1	87.5	81.9	70.5	55.3	45.5	67.0	26.6	28.0	35.2	45.0	54.0	63.2	66.6	64.7	58.4	46.7	36.1	28.2	46.0
Mayfield	37.7	40.8	48.9	58.8	66.8	75.6	78.9	77.9	72.3	61.7	48.5	40.3	59.0	47.9	51.1	60.2	70.4	78.3	87.2	90.8	89.7	85.1	74.8	59.7	50.0	70.4	28.0	30.2	37.6	47.1	55.3	64.2	67.1	65.8	59.8	48.3	37.3	30.2	47.6
Maysville	35.2	37.0	45.0	54.9	64.0	72.9	76.5	74.8	69.1	57.7	45.7	36.7	55.8	44.6	46.9	56.5	67.5	76.9	85.1	88.6	86.6	81.3	70.5	56.3	45.8	67.2	26.0	27.0	33.5	42.2	51.4	60.6	64.4	62.7	57.3	44.8	35.2	27.3	44.4
Princeton	37.1	39.9	48.1	58.2	65.8	75.0	78.3	77.1	71.2	59.9	47.4	38.9	58.1	46.8	50.1	59.6	70.4	78.0	86.4	89.6	88.4	83.0	73.0	58.7	48.5	69.4	27.3	29.3	36.6	45.9	54.3	63.3	67.2	66.0	59.7	46.8	36.2	29.0	46.8
Williamsburg	39.6	41.2	48.8	58.0	65.6	74.2	77.1	76.0	70.6	59.1	47.7	40.3	58.2	51.0	52.5	61.8	72.1	79.4	87.2	90.0	88.6	84.0	73.7	60.5	51.2	71.0	28.2	29.4	35.7	43.8	51.8	61.2	64.8	63.3	57.5	44.5	34.7	29.0	45.3
ILLINOIS																																				
Cairo	37.4	40.6	49.0	60.0	68.8	77.8	81.2	79.5	73.0	62.0	48.6	39.7	59.8	44.9	48.4	57.9	69.0	78.2	87.2	90.7	88.7	82.4	71.7	56.8	47.0	68.6	29.8	32.7	40.1	50.9	59.4	68.4	71.7	70.2	63.6	52.2	40.3	32.3	51.0
INDIANA																																				
Evansville	34.7	37.5	46.6	57.1	65.5	74.6	78.2	76.3	70.5	59.3	46.0	36.9	56.9	43.4	46.5	56.8	67.8	76.5	85.4	89.1	87.0	81.8	71.0	55.6	45.6	67.2	26.0	28.5	36.4	46.3	54.5	63.8	67.3	65.5	59.1	47.6	36.3	28.2	46.6
Paoli	33.7	36.3	44.7	54.8	63.6	72.6	76.5	74.9	68.7	57.4	45.1	35.8	55.3	43.0	45.9	55.7	66.4	75.6	84.1	88.6	87.0	81.1	70.1	55.4	44.9	66.5	24.4	26.5	33.7	43.2	51.6	61.1	64.5	62.9	56.8	44.7	35.0	26.4	44.2
LOUISIANA																																				
Baton Rouge	52.4	55.6	60.3	66.8	73.6	79.6	81.1	80.7	77.5	69.6	59.1	53.6	67.5	61.3	64.5	69.8	76.4	82.8	88.8	90.0	89.7	87.1	80.4	69.3	62.6	76.9	43.4	46.6	50.8	57.2	64.4	70.4	72.2	71.7	67.9	58.8	48.9	44.6	58.1
Cheneyville	52.3	55.4	60.3	67.7	73.8	80.5	82.2	82.2	77.9	68.7	58.6	53.6	67.8	63.7	66.6	71.9	79.2	85.1	91.6	93.3	93.8	90.0	82.4	71.8	65.0	79.5	41.6	44.3	48.7	56.2	62.5	69.3	71.2	70.7	66.1	55.1	45.4	42.0	56.1
Hammond	53.9	56.2	60.3	67.1	73.3	79.6	81.3	81.4	77.7	69.1	59.3	54.3	67.8	65.2	68.0	72.4	78.8	85.0	90.9	91.9	92.4	89.1	82.5	71.9	65.7	79.5	42.5	44.6	48.8	55.4	61.6	68.5	70.7	70.3	66.4	55.8	46.6	42.9	56.2
Lake Charles	52.6	55.9	60.6	68.0	74.5	80.7	82.2	82.3	78.6	70.3	59.3	54.0	68.3	61.8	65.3	70.2	77.6	84.0	89.6	91.1	91.5	88.4	82.0	70.4	63.7	78.0	43.4	46.4	50.9	58.3	64.9	71.7	73.3	73.1	68.7	58.5	48.2	44.3	58.5
New Orleans	54.9	57.4	61.7	68.3	74.6	80.5	81.8	82.2	79.5	71.4	60.9	56.1	69.1	63.2	66.3	70.8	77.5	83.6	89.2	90.1	90.4	87.3	80.3	70.3	64.8	77.8	46.5	48.4	52.5	59.0	65.5	71.8	73.4	74.0	71.6	62.4	51.4	47.3	60.3
Robeline	49.3	52.8	58.2	66.4	72.7	80.0	82.2	82.5	77.3	67.3	56.6	51.2	66.4	60.9	64.5	71.4	78.6	81.8	91.9	94.2	95.2	90.3	82.0	69.9	62.8	78.7	37.6	41.4	45.5	53.9	60.6	68.0	70.4	69.9	64.5	52.7	43.1	39.4	53.9
Ruston P.T.I.	49.3	52.0	58.0	66.4	72.8	80.5	82.7	82.8	77.7	68.0	56.4	49.5	66.3	60.0	63.6	70.2	78.7	84.4	92.2	94.5	95.0	90.2	81.2	68.7	60.2	78.2	38.5	40.5	45.8	54.1	61.1	68.9	71.1	67.9	65.2	54.6	44.4	38.8	54.2
Shreveport	47.8	51.7	57.9	66.8	73.8	81.1	83.6	83.8	78.3	67.8	55.4	49.2	66.4	56.4	61.2	68.0	76.7	83.7	91.0	93.4	94.2	89.1	80.0	66.3	58.5	76.5	39.2	42.1	47.7	56.9	63.9	71.1	73.8	73.4	67.4	55.6	44.5	39.8	56.3
MARYLAND																																				
Baltimore	34.6	35.7	44.0	53.0	64.0	73.0	77.0	74.9	68.6	57.4	46.4	36.5	55.4	42.9	44.4	54.0	63.7	75.0	83.8	87.6	85.3	79.0	67.9	55.7	44.6	65.3	26.3	26.9	33.9	42.3	53.0	62.2	66.4	64.5	58.2	46.8	37.1	28.3	45.5
Cheltenham	35.2	36.1	44.6	53.4	63.5	72.2	76.0	74.2	68.6	57.1	46.8	36.9	55.4	44.5	46.2	55.8	65.4	75.3	83.2	86.7	85.1	79.3	68.8	57.4	45.6	66.1	25.9	25.9	33.5	41.4	51.8	61.1	65.4	63.6	58.0	45.5	36.2	27.3	44.6
Crisfield	39.2	39.8	47.0	55.7	66.1	74.7	78.5	77.2	72.3	61.5	51.0	41.1	58.7	47.4	48.5	56.1	66.0	75.6	83.2	86.4	85.5	80.8	70.5	59.7	49.0	67.4	31.4	31.3	37.8	46.0	56.6	66.2	70.7	69.2	63.9	52.6	42.7	33.0	50.1
Easton Pol. Brks.	36.1	36.8	44.9	53.4	63.8	72.7	76.6	74.8	69.1	57.6	47.8	37.6	55.9	44.7	46.0	55.3	64.6	75.1	83.4	86.7	85.4	79.9	68.8	57.8	45.9	66.1	27.4	27.5	34.5	42.1	52.8	62.1	66.5	64.6	58.5	46.7	38.0	28.9	45.8
Snow Hill	37.6	38.2	45.1	52.9	63.1	72.2	75.8	74.4	68.9	58.0	47.8	39.4	56.1	47.8	48.3	55.7	64.1	74.2	83.0	86.1	84.9	79.3	69.7	59.0	49.4	66.8	27.9	28.2	34.3	41.5	51.7	61.3	65.8	64.1	58.8	46.7	36.8	29.1	45.5
Solomons	38.1	38.6	46.0	54.6	65.3	74.2	78.3	77.1	72.0	60.6	50.2	40.2	57.9	45.9	46.8	55.3	63.9	74.2	82.8	86.4	85.3	79.7	69.1	57.5	47.5	66.2	30.5	30.3	36.7	45.4	56.3	65.9	70.3	69.2	64.2	52.6	42.7	32.6	49.7
MISSISSIPPI																																				
Booneville	43.0	45.6	52.4	61.5	69.4	77.8	80.1	79.4	74.8	64.0	52.1	44.8	62.1	52.7	55.3	63.5	72.7	80.3	88.6	91.1	90.7	86.7	76.6	63.6	54.5	73.0	33.4	35.5	41.5	50.3	58.4	66.8	69.4	68.4	63.0	51.3	40.6	34.5	51.1
Brookhaven	51.3	53.3	58.7	66.2	73.3	80.2	81.9	81.7	77.7	68.4	57.5	51.5	66.8	62.2	64.6	70.7	78.5	85.5	92.0	93.4	93.5	89.8	81.6	69.8	62.4	78.7	40.0	42.0	46.7	53.9	61.2	68.3	70.2	70.1	65.9	55.5	45.1	40.4	54.9
Clarksdale	44.9	48.0	55.6	65.0	72.5	80.5	82.8	82.5	76.7	66.2	53.9	46.6	64.6	54.5	58.0	66.7	76.5	84.1	91.8	94.2	94.3	88.8	79.2	65.2	55.9	75.8	35.3	38.0	44.4	53.4	60.9	69.1	71.8	71.0	65.1	53.4	42.8	37.1	53.5
Forest	48.6	51.6	56.6	64.1	71.2	78.1	80.0	80.0	75.5	65.3	55.2	49.1	64.6	59.8	61.7	68.8	76.4	83.4	90.0	91.4	91.5	87.7	79.0	68.0	60.5	76.5	37.4	40.3	44.4	51.9	59.0	66.3	68.8	68.4	63.6	51.6	42.5	37.5	52.6
Hattiesburg	51.4	54.0	58.9	66.7	73.6	80.4	82.0	81.5	77.3	67.5	57.3	51.8	66.9	63.2	66.0	70.9	79.3	85.9	92.5	93.3	93.1	89.1	81.4	70.8	63.7	79.1	39.6	42.0	46.9	54.0	61.3	68.5	70.8	70.0	65.7	53.6	43.8	39.5	54.6
Jackson	48.3	51.0	56.8	64.9	72.3	79.9	82.1	81.4	76.7	66.4	55.2	49.0	65.4	58.6	61.5	68.1	76.0	83.7	91.4	93.6	93.1	88.7	79.7	67.2	59.4	76.8	37.9	40.4	45.5	53.7	60.8	68.3	70.5	69.7	64.7	53.1	43.1	38.6	53.9
Meridian	47.5	50.7	56.5	64.3	71.5	79.1	80.9	80.5	75.9	64.7	54.1	48.2	64.5	58.5	62.1	68.4	76.7	83.8	90.7	92.0	91.9	87.4	78.3	66.7	59.5	76.3	36.5	39.3	44.6	51.8	59.2	67.4	69.8	69.1	64.4	51.1	41.4	36.8	52.6
Moorhead	46.2	49.3	54.4	64.5	71.8	79.7	81.9	81.3	76.1	65.2	53.8	47.3	64.3	56.4	59.7	67.7	76.2	83.9	91.7	93.7	93.5	88.2	78.5	68.0	57.6	76.3	36.0	38.9	43.4	53.3	59.9	67.7	70.4	69.5	61.7	51.8	43.3	36.7	52.7
Natchez	51.0	54.1	59.4	66.6	72.9	79.7	81.6	81.7	77.5	68.0	57.4	52.1	66.8	61.6	64.9	70.0	78.0	84.0	90.4	92.1	92.9	88.9	80.4	69.2	62.5	77.9	40.4	43.4	48.8	55.2	61.9	69.0	71.4	70.7	66.3	55.7	45.8	41.4	55.8
Poplarville	53.6	56.1	60.8	67.5	74.2	80.2	81.7	81.6	78.3	70.6	60.3	54.6	68.3	64.4	67.1	71.5	78.4	85.1	90.6	91.9	92.0	88.8	82.2	71.7	64.8	79.0	43.7	45.3	50.1	56.7	63.3	69.7	71.6	71.4	67.5	58.8	48.8	44.1	57.6
State College	47.0	49.4	55.8	64.0	71.6	79.4	81.6	81.0	76.6	63.5	54.6	47.9	64.4	57.4	60.2	67.2	75.8	83.1	91.0	93.2	92.8	89.0	79.5	66.1	58.3	76.1	36.6	38.6	44.3	52.2	58.0	67.8	70.3	69.6	64.6	51.0	43.0	37.3	52.8
Vicksburg	49.2	52.1	58.1	65.8	72.9	79.5	81.5	81.5	77.0	67.7	56.8	50.5	66.1	57.6	60.9	67.4	75.1	82.1	88.4	90.0	90.3	86.3	77.6	66.2	58.7	75.1	40.8	43.3	48.7	56.5	63.6	70.6	72.9	72.6	67.7	57.8	47.3	42.2	57.0
Water Valley	44.8	47.7	54.3	63.1	70.1	78.4	81.1	80.6	75.7	65.4	53.7	46.1	63.4	55.4	58.6	66.0	75.0	81.8	90.3	93.2	93.1	88.5	79.4	66.0	56.8	75.3	34.3	36.8	42.6	51.1	58.3	66.4	69.3	68.2	63.2	51.4	41.1	35.2	51.5
Waynesboro	50.9	53.1	57.9	65.4	72.4	79.4	80.9	80.4	76.3	66.5	55.8	50.7	65.8	62.4	65.3	70.1	78.3	84.6	91.0	92.0	91.8	88.3	80.3	69.0	62.5	78.0	38.6	41.3	45.6	52.4	60.3	67.8	70.0	69.2	64.5	52.8	42.5	38.6	53.6
MISSOURI																																				
Clinton	31.9	36.4	45.3	56.8	65.7	75.1	80.2	79.5	71.3	60.0	45.3	35.5	56.9	41.3	46.5	56.4	68.3	77.3	86.5	92.9	91.5	83.9	72.4	56.2	45.0	68.2	22.5	25.9	34.2	45.2	54.1	63.7	67.7	67.9	58.9	47.6	34.6	25.9	45.7
Columbia	29.8	33.7	42.8	54.9	63.6	72.9	77.8	76.2	68.7	58.1	43.2	33.1	54.6	38.8	43.1	53.0	65.0	74.0	82.9	88.8	87.0	79.5	69.1	52.9	41.9	64.7	20.7	24.3	32.6	43.9	53.2	62.9	66.8	65.4	57.9	47.0	33.4	24.3	44.4
Farmington	34.1	37.6	45.8	56.4	64.5	73.8	77.9	76.6	69.6	58.4	45.5	36.8	56.4	43.8	47.8	57.2	68.1	76.4	85.5	90.6	89.2	82.0	71.6	56.3	46.2	67.9	24.4	27.1	34.4	44.7	52.5	62.2	65.3	64.2	57.5	45.5	34.8	27.1	45.0
Kansas City	30.0	34.6	43.8	55.8	65.5	75.4	80.9	79.0	70.6	59.6	44.3	33.7	56.1	39.0	44.3	54.1	66.0	75.3	85.2	91.2	89.3	81.1	70.2	53.9	42.3	66.0	21.0	24.8	33.5	45.6	55.6	65.6	70.5	68.7	60.1	48.9	34.7	25.1	46.2
Lebanon	32.8	36.3	44.2	54.9	63.3	72.7	77.6	76.5	69.1	58.6	44.8	35.9	55.6	43.9	47.7	56.4	67.0	75.3	84.4	90.8	89.8	81.9	71.8	56.5	46.2	67.6	21.8	25.0	32.1	42.7	51.3	60.9	64.7	63.9	56.5	45.5	33.4	25.2	43.6
Nevada	33.7	38.3	46.7	57.6	65.5	74.9	79.5	78.8	71.3	60.5	46.4	37.2	57.5	43.6	48.8	58.4	69.2	76.8	85.7	91.4	91.3	83.9	73.2	57.7	47.3	68.9	23.6	27.3	34.9	46.0	54.2	64.2	67.6	66.7	59.4	48.0	35.3	27.5	46.2
Poplar Bluff	36.7	40.4	48.5	59.2	67.2	76.1	80.0	78.7	71.9	60.7	48.0	39.1	58.9	46.9	51.6	60.5	71.5	79.6	88.2	92.3	91.3	84.9	74.7	60.3	49.7	71.0	26.1	29.0	36.4	46.8	54.9	64.0	67.4	66.4	58.9	46.6	35.7	28.1	46.7
Rolla Sch. Min.	33.4	36.8	45.4	56.5	64.6	73.5	78.2	77.1	69.7	59.3	45.5	36.2	56.4	43.0	46.9	56.4	67.7	75.3	83.8	89.6	88.6	80.9	70.6	55.8	45.1	67.0	23.7	26.4	34.5	45.3	54.0	63.3	67.1	66.0	58.8	47.9	35.5	27.1	45.8
Salem	33.5	37.1	45.4	55.9	63.9	72.9	77.4	76.2	68.7	58.2	45.1	36.1	55.9	43.6	47.7	57.0	67.9	75.7	84.3	90.0	88.8	80.9	70.9	56.1	45.9	67.4	23.4	26.4	33.7	43.9	52.1	61.5	65.0	64.1	56.7	45.4	33.8	26.1	44.3
Seligman	36.3	39.9	47.5	57.8	64.5	73.2	77.5	77.4	70.4	60.7	47.5	39.2	57.7	44.6	50.7	59.0	69.3	75.0	83.2	88.2	88.5	81.8	72.1	58.4	49.3	68.3	27.1	28.9	36.0	46.7	54.0	63.1	66.8	66.3	58.1	49.2	36.7	29.0	46.8

TEMPERATURE DATA FOR SELECTED STATIONS IN AND NEAR THE SOUTHERN PINE REGION

Table 1. (Continued)

	AVERAGE MONTHLY TEMPERATURE													AVERAGE MAXIMUM MONTHLY TEMPERATURE												AVERAGE MINIMUM MONTHLY TEMPERATURE												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual	January	February	March	April	May	June	July	August	September	October	November	December	Annual	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
MISSOURI (Cont'd.)																																					
Springfield	32.7	36.8	44.9	55.5	63.6	72.9	77.5	76.5	69.1	58.4	44.5	35 7	55.7	41.7	46.7	55.3	65.8	73.5	82.5	87.7	86.9	79.3	68.9	54.0	44.3	65.6	23.7	26.9	34.5	45.1	53.6	63.3	67.2	66.0	58.8	47.8	34.9	27.1	45.7
St. Louis	32.2	35.7	44.4	55.6	65.4	75.1	79.7	77.7	70.4	59.4	45.0	35.1	56.3	40.8	44.5	54.2	65.8	75.5	85.1	90.0	87.9	80.7	69.7	54.0	43.3	66.0	23.6	26.8	34.6	45.4	55.2	65.0	69.3	67.4	60.1	49.0	35.9	26.9	46.6
NEW JERSEY																																					
Atlantic City	35.8	35.4	41.5	49.4	59.1	68.7	73.6	73.1	68.3	58.0	48.1	38.2	54.1	42.4	42.1	48.3	56.1	65.4	75.0	79.3	78.8	74.1	64.8	54.7	44.9	60.5	29.1	28.6	34.7	42.6	52.7	62.4	67.9	67.4	62.4	51.2	41.4	31.4	47.7
NORTH CAROLINA																																					
Albemarle	43.2	45.0	51.6	59.8	68.5	76.7	79.0	77.7	73.1	61.6	50.8	43.3	60.9	55.0	57.5	65.1	74.1	82.5	90.1	91.4	90.5	85.9	76.5	64.8	55.3	74.1	31.4	32.5	37.9	45.3	54.0	63.3	66.3	65.1	60.1	46.7	37.1	31.1	47.6
Asheville	39.4	40.8	46.8	55.5	63.4	71.3	73.8	72.7	67.9	57.0	46.6	40.2	56.3	48.8	50.6	57.4	66.9	74.8	82.2	84.1	82.8	78.5	68.5	57.0	49.7	66.8	30.0	30.9	36.2	44.1	52.0	60.3	63.4	62.5	57.3	45.5	36.2	30.6	45.8
Charlotte	42.3	44.4	51.0	59.7	68.3	76.6	78.6	77.3	72.6	61.5	50.4	43.0	60.5	52.2	54.9	62.4	71.4	79.8	87.6	88.8	87.4	83.1	73.1	61.4	53.0	71.3	32.3	33.8	39.5	47.9	56.8	65.6	68.3	67.2	62.1	49.8	39.4	33.0	49.6
Durham	41.5	43.1	50.1	58.7	67.4	75.6	78.1	76.7	71.9	60.4	49.8	41.9	59.6	52.2	54.5	62.7	72.1	80.1	87.4	89.1	87.7	83.4	73.5	62.3	52.7	71.5	30.7	31.7	37.5	45.3	54.7	63.8	67.2	65.5	60.4	47.3	37.1	31.1	47.7
Fayetteville	46.1	47.2	54.0	62.1	70.1	78.0	80.1	78.7	74.8	63.6	53.7	46.0	62.9	58.1	59.2	67.0	75.9	82.8	89.8	90.6	89.6	86.1	77.0	67.1	57.8	75.1	34.1	35.2	41.0	49.1	57.4	66.2	69.5	67.9	63.5	50.1	39.2	34.1	50.6
Goldsboro	45.1	46.6	53.8	62.0	70.2	78.1	80.3	78.9	74.6	63.3	53.5	45.6	62.7	56.2	58.4	66.8	75.7	83.7	90.6	91.8	90.5	86.4	76.7	66.3	57.3	75.0	34.0	34.8	40.8	48.4	56.8	65.4	68.8	67.7	62.9	50.1	40.9	34.1	50.4
Hickory	41.6	43.4	49.9	58.7	66.9	75.0	77.2	75.8	71.4	60.6	49.5	42.2	59.4	51.3	53.6	61.4	70.8	78.8	86.5	87.7	86.6	82.4	73.0	60.9	52.5	70.5	31.6	32.8	38.4	46.6	55.0	63.5	66.5	65.3	60.5	48.2	38.3	31.6	48.2
Highlands	39.6	40.2	45.7	54.3	61.6	68.3	70.2	69.6	65.7	56.5	46.3	40.7	54.9	49.4	50.8	56.8	66.3	73.4	79.5	80.5	79.8	76.3	68.2	57.6	50.7	65.8	29.8	29.7	34.3	42.3	49.6	57.2	60.1	59.5	55.2	44.8	35.5	30.3	44.0
Lumberton	46.0	47.7	54.6	62.6	70.1	77.5	79.5	78.3	74.5	63.2	53.0	46.0	62.8	56.7	59.0	66.8	75.6	82.5	89.2	90.3	89.2	85.7	76.1	65.4	56.8	74.4	35.4	36.5	42.4	49.6	57.8	65.8	68.8	67.6	63.2	50.6	40.9	35.1	51.1
New Holland	46.3	47.0	53.1	60.7	68.5	75.9	78.6	77.9	74.3	64.1	55.0	47.9	61.6	56.8	57.8	64.2	71.6	78.9	85.4	87.4	86.5	83.3	74.4	66.1	58.4	72.6	35.9	36.3	41.9	49.8	58.0	66.3	69.8	69.3	65.2	53.9	43.9	37.3	52.3
Pinehurst	44.1	45.8	52.6	61.1	69.1	76.9	78.9	77.6	73.2	62.3	51.9	44.3	61.5	54.8	57.5	65.4	74.9	82.7	89.8	90.7	89.6	85.1	75.4	64.2	54.8	73.7	33.3	34.1	39.8	47.3	55.5	64.1	67.1	65.8	61.3	49.2	39.9	33.5	49.2
Raleigh	41.4	43.1	50.1	58.5	67.3	75.7	78.5	77.2	72.6	61.1	50.4	42.4	59.9	50.8	53.4	61.6	70.9	79.3	87.1	89.0	87.8	83.5	73.2	61.5	52.1	70.9	32.0	32.7	38.5	46.1	55.3	64.2	68.0	66.6	61.6	48.9	39.2	32.6	48.8
Weldon	42.1	43.6	50.9	59.6	68.8	77.2	79.8	78.2	73.1	61.4	51.2	43.0	60.7	52.1	54.4	63.0	72.4	81.3	89.1	90.9	89.6	84.4	73.8	63.0	53.0	72.2	32.4	32.8	38.7	46.8	56.3	65.2	69.0	67.0	62.0	49.0	39.6	32.7	49.3
Wilmington	47.8	48.7	54.7	62.2	70.0	77.6	80.0	79.3	75.4	65.3	55.7	48.6	63.8	58.7	59.8	65.9	73.4	80.5	87.3	89.1	88.4	84.8	76.1	66.8	59.5	74.2	36.9	37.5	43.5	50.9	59.5	67.9	70.9	70.2	66.0	54.5	44.6	37.7	53.3
Winston-Salem	39.3	41.2	48.5	57.5	66.7	74.9	77.5	76.2	70.9	59.8	48.6	40.6	58.5	48.6	50.9	59 0	68.6	77.8	85.5	87.0	85.7	80.6	70.8	59.0	49.7	68.6	30.0	31.5	38.0	46.4	55.6	64.3	67.9	66.7	61.1	48.7	38.1	31.5	48.3
OKLAHOMA																																					
Ada	40.6	45.8	52.7	62.6	69.3	78.2	82.5	82.7	75.3	65.0	52.0	43.8	62.5	51.1	56.9	64.4	74.0	80.0	88.8	94.1	95.0	87.2	77.1	63.3	54.1	73.8	30.7	34.5	40.9	51.1	58.6	67.5	71.2	70.8	63.5	53.1	40.7	33.2	51.3
McAlester	40.4	45.1	52.6	62.6	69.1	78.1	82.2	82.7	75.2	64.8	49.7	42.8	62.1	50.9	55.7	64.4	73.9	79.9	88.8	94.3	95.6	88.6	77.7	63.3	53.4	73.9	29.9	34.0	41.0	51.2	58.2	67.4	70.6	70.5	62.4	52.0	40.0	32.5	50.8
Marlow	39.9	44.9	52.3	62.5	69.5	78.1	82.4	82.9	75.2	64.9	51.6	42.7	62.2	51.2	56.9	65.7	74.9	81.1	89.7	95.0	95.9	88.0	77.4	63.7	53.8	74.4	28.7	32.5	39.1	50.0	57.9	66.5	69.9	69.7	62.5	52.3	39.5	31.5	50.0
Muskogee	39.4	43.9	51.7	62.0	69.0	77.8	82.1	82 5	75.1	64.3	50.8	42 2	61.7	49.4	54.4	63 1	73.1	79 7	88.3	93.6	94.9	87.6	77.0	62.3	52.1	73.0	29.5	33.2	40.3	50.7	58.4	67.4	70.7	70.5	63.2	51.8	39.5	32.2	50.6
Newkirk	34.4	40.0	48.4	59.0	67.0	76.7	82.0	81.5	73.3	62.2	47.6	38.3	59.2	44.5	51.4	60.8	70.7	78.2	87.8	94.0	93.9	85.3	74.1	59.2	48.3	70.7	24.6	28.6	36.0	47.2	55.8	65.7	69.9	69.5	61.3	50.3	36.2	28.2	47.8
Okemah	39.3	44.0	51.5	61.5	68.5	77.4	81.6	82.0	74.6	64.3	50.7	42.4	61.5	49.5	54.5	63.0	72.7	79.0	88.0	93.1	94.3	86.5	76.2	62.1	52.5	72.6	29.0	33.2	40.0	50.4	58.1	66.7	70.0	69.6	62.5	52.4	39.4	32.3	50.3
Oklahoma City	37.8	42.5	50.3	60.9	68.6	78.0	82.6	82.2	74.6	63.8	49.7	40.9	61.0	47.2	52.7	61.5	71.6	78.6	88.1	93.1	92.8	85.3	74.5	60.0	50.2	71.3	28.3	32.3	39.0	50.2	58.5	67.9	71.8	71.6	63.8	53.1	39.4	31.6	50.6
Tulsa	37.4	42.0	49.9	60.7	68.2	77.5	82.1	81.9	73.8	63.4	49.6	40.8	60.6	46.9	52.3	61 0	71.4	78.3	87.6	93.1	93.1	85.0	74.9	60.2	50.4	71.2	27.9	31.6	38.8	50.0	58.0	67.4	71.1	70.6	62.6	51.8	38.9	31.2	50.0
Pawhuska	36.3	41.1	49.5	60.4	67.7	77.0	81.5	81.6	73.4	62.5	48.5	39.3	59.9	48.2	53.6	62.9	72.8	79.1	87.9	93.6	94.1	86.4	76.1	61.4	50.9	72.3	24.3	28.2	36.4	48.1	56.2	66.0	69.4	69.0	60.4	49.3	35.5	27.8	47.6
Wichita Mt.	38.7	43.1	51.2	61.2	68.1	77.3	81.7	81.7	73.7	62.8	49.4	40.9	60.8	51.6	56.4	65.5	75.1	80.8	89.4	94.8	95.2	86.6	76.3	62.8	53.5	74.0	26.3	29.8	36.6	47.2	55.4	64.9	68.6	68.3	60.5	49.3	35.9	28.3	47.6
PENNSYLVANIA																																					
Harrisburg	31.1	32.1	40.8	50.9	62.4	71.1	75.4	73.0	66.1	55.2	44.0	33.9	53.0	38.6	40.1	49.8	61.1	73.1	81.5	85.6	83.0	75.8	65.0	52.1	40.6	62.2	23.6	24.1	31.8	40.7	51.6	60.6	65.1	62.9	56.4	45.3	35.9	27.2	43.8
Reading	32.2	32.8	41.6	51.3	62.5	71.3	75.7	73.4	67.1	56.1	45.4	34.8	53.7	39.1	40.2	50.2	60.9	72.6	81.0	85.2	82.8	76.5	65.7	53.0	41.4	62.4	25.3	25.3	32.9	41.7	52.4	61.5	66.1	64.0	57.6	46.5	37.7	28.1	44.9
SOUTH CAROLINA																																					
Charleston	50.3	51.9	57.2	64.3	71.4	77.9	80.1	79.6	76.3	66.5	56.3	50.5	65.2	61.4	63.0	68.5	76.0	82.5	87.9	89.4	88.8	85.6	77.4	68.1	62.0	75.9	39.2	40.7	45.8	52.5	60.2	67.9	70.8	70.3	66.9	55.6	44.5	39.0	54.5
Columbia	47.0	48.5	55.2	63.5	71.7	79.5	81.4	80.0	75.9	64.9	53.9	47.0	64.0	58.1	60.2	67.1	75.9	83.8	90.8	91.9	90.4	86.6	77.2	65.9	58.2	75.5	35.9	36.8	43.2	51.1	59.6	68.2	70.8	69.6	65.1	52.5	41.8	35.8	52.5
Florence	46.3	47.6	55.4	63.4	71.3	79.0	80.9	79.3	75.3	64.1	53.6	46.5	63.6	56.3	58.0	66.9	75.2	83.2	90.4	91.1	89.7	86.1	76.5	65.7	56.8	74.7	36.3	37.2	43.8	51.6	59.3	67.6	70.6	68.8	64.4	51.6	41.4	36.1	52.4
Greenville	43.3	45.3	51.5	60.2	68.5	76.6	78.4	77.2	73.1	62.5	51.3	44.1	61.0	51.6	54.3	61.5	70.7	79.1	86.9	87.9	86.4	82.3	72.2	60.5	52.3	70.5	35.0	36.2	41.5	49.6	57.9	66.3	68.8	68.0	63.9	52.8	42.0	35.8	51.5
Heath Springs	45.4	47.0	53.2	61.2	69.2	76.9	78.8	77.4	73.5	63.2	53.0	45.5	62.0	55.2	57.3	64.0	72.8	80.6	87.8	88.7	87.5	83.9	74.9	64.1	54.9	72.6	35.6	36.8	42.4	49.5	58.0	66.0	68.8	67.5	63.3	51.4	42.2	35.9	51.4
Newberry	46.0	47.8	54.3	62.5	70.7	78.7	80.9	79.5	75.3	63.8	52.8	46.0	63.2	57.1	59.4	66.6	75.4	83.4	90.8	92.0	90.6	86.6	76.8	64.9	56.5	75.0	34.1	36.5	42.0	49.6	58.0	66.7	69.8	68.7	63.9	50.8	40.7	35.1	51.3
Orangeburg	48.9	50.7	56.9	64.5	72.0	79.0	80.8	79.8	75.8	65.4	55.1	48.6	64.8	60.1	62.4	69.2	77.3	84.4	90.3	91.3	90.7	86.9	77.8	67.2	59.7	76.4	37.7	38.9	44.6	51.6	59.6	67.8	70.4	69.4	65.0	53.0	43.2	37.4	53.2
Spartanburg	43.4	45.4	51.7	60.5	68.8	77.2	78.9	77.7	73.2	62.2	51.2	43.9	61.2	52.1	55.0	62.1	71.4	79.7	87.7	88.7	87.1	82.8	72.8	61.1	52.5	71.1	34.7	35.8	41.3	49.5	57.9	66.7	69.1	68.2	63.5	51.5	41.3	35.2	51.2
TENNESSEE																																					
Chattanooga	41.6	44.0	50.7	59.7	67.7	75.8	78.3	77.3	72.5	60.8	49.1	42.1	60.0	51.6	54.6	62.2	71.8	79.9	87.6	89.6	88.7	84.6	73.9	60.8	52.2	71.5	31.6	33.3	39.1	47.5	55.5	64.0	67.0	65.9	60.3	47.7	37.4	31.9	48.4
Clarksville	39.7	42.4	50.3	60.1	68.0	76.8	80.0	78.9	73.1	61.6	49.5	41.4	60.2	49.3	52.3	61.8	72.4	80.6	89.1	92.2	91.0	86.1	74.9	60.6	51.0	71.8	30.0	32.3	38.9	47.8	55.5	64.5	67.9	66.8	60.5	48.1	38.4	31.5	48.5
Crossville	37.8	39.6	46.1	55.4	63.6	70.8	73.6	72.4	68.1	57.1	45.9	38.9	55.8	47.8	50.3	57.7	67.4	76.1	82.9	85.3	84.2	79.8	70.5	56.7	48.6	67.3	27.5	28.5	34.5	43.2	51.0	58.7	61.9	60.6	55.6	43.9	34.4	27.8	44.0
Jackson	40.7	43.6	50.9	60.2	67.9	76.5	79.4	78.4	72.7	61.6	49.7	42.4	60.3	50.4	53.6	62.0	71.8	79.6	88.1	91.2	90.2	85.1	75.2	61.2	51.9	71.7	30.9	33.5	39.8	48.6	56.2	64.9	67.7	66.7	60.6	48.1	38.4	32.5	49.0
Knoxville	40.5	42.5	49.4	59.0	67.4	75.8	78.4	77.0	72.1	60.3	48.4	41.0	59.3	49.8	52.5	60.5	70.8	79.0	87.0	89.1	87.8	83.5	72.5	59.1	50.3	70.2	31.1	32.4	38.3	47.2	55.8	64.5	67.6	66.1	60.6	48.1	37.6	31.7	48.4
Lewisburg	40.3	42.7	49.8	59.0	67.0	75.6	78.7	77.7	72.4	60.5	48.6	41.7	59.5	50.3	53.2	61.6	70.8	79.4	87.9	90.9	90.0	85.2	74.0	60.2	51.3	71.2	30.7	32.7	38.5	46.8	54.9	63.6	67.3	65.7	59.8	46.5	37.1	31.5	47.9
Memphis	41.6	44.5	52.0	61.8	70.1	78.3	81.2	80.3	74.3	63.6	50.6	43.3	61.8	50.3	53.2	62.0	72.0	80.4	88.4	91.1	90.7	85.3	75.6	61.4	52.6	71.9	32.9	35.8	42.0	51.5	59.7	68.2	71.3	69.8	63.2	51.5	39.8	33.9	51.6
Nashville	39.9	42.3	49.8	59.7	68.2	76.9	80.0	78.7	73.2	61.8	49.3	41.6	60.1	48.9	51.6	60.1	70.5	79.1	87.7	90.6	89.4	84.6	73.8	59.2	50.5	70.5	30.9	33.0	39.5	48.8	57.2	66.1	69.3	68.0	61.8	49.8	39.3	32.6	49.7
Rogersville	40.1	41.9	48.8	57.9	65.8	73.8	76.6	75.8	71.6	59.9	48.0	40.5	58.4	50.2	53.1	61.2	71.1	78.6	86.0	87.9	87.7	84.3	73.8	60.2	50.4	70.4	29.9	30.9	36.4	44.8	52.9	61.6	65.0	63.9	58.8	45.9	35.8	30.0	46.3
Union City	37.5	40.8	48.8	59.2	68.0	77.1	80.2	79.0	72.7	61.0	48.2	39.9	59.4	47.1	50.4	59.6	70.6	79.9	89.0	92.4	91.3	85.6	74.8	59.5	49.5	70.8	28.0	30.7	37.8	47.6	56.1	65.1	68.2	66.9	60.0	47.3	37.0	30.1	47.9
Waynesboro	40.1	42.3	49.7	58.9	65.8	74.3	77.3	76.3	71.2	59.9	48.3	41.5	58.8	51.1	54.2	62.4	72.3	78.9	87.1	90.2	89.4	84.9	74.8	61.5	53.0	71.7	28.6	30.4	37.0	45.7	52.4	61.3	64.3	63.3	57.7	44.8	35.3	29.9	45.9
TEXAS																																					
Austin	49.9	54.1	60.3	67.9	75.2	81.5	84.1	84.5	79.3	70.9	59.2	52.2	68.2	59.8	64.4	71.3	78.6	85.3	91.4	94.4	95.4	89.7	82.1	70.1	62.3	78.7	40.0	43.7	49.2	57.2	65.0	71.6	73.7	73.5	68.8	59.6	48.2	42.0	57.7
Beeville	55.1	58.9	64.5	71.3	77.0	81.7	83.8	84.3	80.3	73.5	63.5	57.1	70.9	65.6	69.9	75.9	82.4	87.7	92.0	95.0	96.2	91.3	85.8	75.2	67.7	81.7	44.9	47.8	53.2	60.2	66.4	71.3	72.7	72.4	69.3	61.2	51.8	46.5	59.8
Brownwood	45.4	49.8	56.6	65.1	72.5	80.3	84.0	84.1	76.9	67.5	55.4	47.9	65.5	58.9	63.7	70.2	79.3	85.2	92.8	97.2	97.9	89.7	81.2	69.6	61.7	79.0	31.8	35.8	41.9	50.8	59.8	67.8	71.2	70.5	64.1	54.2	41.3	34.1	51.9
Corpus Christi	55.9	59.4	64.3	71.0	76.6	81.0	82.7	83.0	80.2	73.9	64.3	58.0	70.8	65.3	68.9	73.6	79.1	84.5	88.7	91.2	92.0	88.6	83.3	74.1	67.5	79.7	46.5	49.8	55.0	62.9	68.6	73.2	74.1	73.9	71.8	64.5	54.4	48.4	61.9

TEMPERATURE DATA FOR SELECTED STATIONS IN AND NEAR THE SOUTHERN PINE REGION

Table 1. (Continued)

STATION	AVERAGE MONTHLY TEMPERATURE												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
TEXAS (Cont'd.)													
Dallas	45.7	49.8	57.4	66.3	73.7	81.9	85 5	85.8	78.9	68.8	55.8	48.3	66.5
Eastland	43.4	47.8	55.2	64.4	71.5	79.9	83.5	83.8	76.4	66.4	54.4	46.6	64.4
Fort Worth	45.2	49.3	56.5	65.6	72.9	81.0	84.6	85.3	78.2	68.3	55.6	47.8	65.9
Gainesville	43.4	48.3	55.7	64.6	72.0	80.3	84.2	84.5	77.6	66.9	54.3	46.3	64.8
Galveston	54.3	57.3	61.8	69.1	75.9	81.8	83.3	83.7	80.4	73.8	63.4	56.5	70.1
Greenville	43.3	47.6	55.0	64.5	72.1	80.6	84.1	84.8	77.9	67.5	54.4	46.3	64.8
Huntsville	50.4	53.6	59.4	67.3	74.2	80.9	83.0	83.5	78.2	70.0	58.3	52.1	67.6
Liberty	53.7	57.2	62.0	68.8	74.9	80.8	82.9	83.1	78.9	71.0	60.8	55.4	69.1
Luling	50.7	54.9	61.2	69.0	76.4	82.9	85.0	85.4	79.9	71.3	59.8	53.0	69.1
Marshall	47.3	51.3	57.6	66.0	73.0	80.9	83.7	84.2	78.5	68.5	56.1	49.7	66.4
Mexia	46.4	50.4	56.8	65.5	72.8	80.1	83.6	84.6	78.8	69.2	56.7	49.2	66.2
Nacogdoches	48.2	51.9	57.5	65.0	71.6	78.8	81.6	82.1	77.0	67.7	56.2	50.0	65.6
Palestine	48.4	52.3	58.1	66.2	72.9	80.0	82.5	83.1	77.7	69.0	57.5	50.8	66.5
Paris	42.8	46.8	53.8	63.4	71 0	79.7	83.2	83.7	76.9	66.5	53.5	45.7	63.9
Port Arthur	52.9	56.0	60.3	67.9	74.4	80.1	81.7	81.8	77.9	70.5	59.3	54.1	68.1
San Antonio	50.6	55.1	61.4	68.8	76.0	82.0	84 2	84.4	79.4	71.3	59.8	53.1	68.8
Sealy	52.8	57.0	62.1	70.1	76.4	82.1	83.9	84.7	79.6	72.1	61.7	55 5	69.8
Victoria	55.2	58.9	63.9	70.6	77.4	83.1	84.8	85.3	80.8	73.6	63.8	56.8	71.2
Waco	47.3	51.7	58.4	66.8	74.5	81.8	85.0	85.5	78.9	69.4	57.8	50.2	67.3
Wichita Falls	40.6	45.8	53.0	62.6	70.5	79.6	83.8	84.2	76.4	65.3	51.7	43.8	63.1
VIRGINIA													
Cape Henry	42.5	42.3	48.7	56.1	65.5	74.2	77.7	76.4	73.0	62.8	52.8	44.1	59.7
Charlottesville	36.8	38.5	46.4	55.8	65 8	73.7	77.0	75.4	70.1	59.2	48.3	38.9	57.2
Clarksville	39.0	40.6	48.2	57.7	66.7	75.1	77.9	76.1	70.8	58.0	47.7	39.5	58.1
Danville	41.1	42.6	49.8	58.8	67.7	76.3	79.0	77.5	72.4	60.6	49.9	41.8	59 8
Fredericksburg	37.2	38.7	46.7	55.4	64.9	73.2	76.8	74.9	69.7	58.4	48.1	38.7	56.9
Hot Springs	32.4	33.6	41.3	50.5	59.5	66.9	69.8	68.1	62.9	52.2	41.6	33.8	51.1
Lynchburg	37.7	39.2	46.4	55.5	65.0	72.8	76.0	74.2	68.8	57.8	47.3	38.9	56.6
Norfolk	41.5	42.0	49.1	56.3	65.9	74.7	77.5	76.4	72.0	61.2	51.4	42.8	59.2
Richmond	38.3	39.7	47.5	56.1	65.8	74.3	77.5	75.9	70.3	58.8	48.4	39.5	57.7
Roanoke	37.9	39.2	46.3	55.5	64.7	72.7	75.9	74.3	69.1	57.9	46.9	39.0	56.6
Wytheville	35.9	36.9	43.7	52.6	61.0	68.8	71.7	70.4	65.5	54.7	43.9	36.6	53.5
WEST VIRGINIA													
Bayard	29.5	29.8	36.8	46.2	55.6	63.9	66.9	65.4	59.9	49.5	39.0	30.5	47 8
Charleston	36.4	38.2	44.9	55.0	63.7	72.0	75.4	73.6	68.6	57.4	45.8	38.1	55.8
Gary	36.0	37.1	43.5	53.7	62.4	70.4	73.5	72.5	67.5	55.6	44.6	37.1	54.5
Huntington	38.0	39.0	47.2	57.3	65.7	74.1	76.9	75.4	70.5	59.2	46.7	39.1	57.4
Elkins	32.2	32.5	39.3	49.1	58.2	66.5	70.0	68.2	63.0	51.7	40.8	32.9	50.4
Mannington	33.0	33.9	41.7	51.1	60.4	68.9	71.8	70.1	64.5	53.5	42.6	34.1	52.1
Martinsburg	32.6	33.9	42.4	52.2	63.2	72.2	76.5	73.9	67.4	55.3	44.4	34.6	54.1
Parkersburg	34.4	35.5	43.6	53.8	63.5	72.4	75.7	74.0	68.4	56.9	45.0	36.1	54.9
Pickens	30.0	31.3	38.6	47.5	56.8	64.5	67.5	65.4	61.2	50.2	40.2	31.5	48.7
Union	34.2	35.4	42.4	52.3	61.0	68.8	71.7	70.3	65.7	54.1	42.8	34.8	52.8
DIST. OF COLUMBIA													
Washington	36.2	37.1	45.3	54.4	64.7	73.4	77.3	75.4	69.6	58.2	47.7	38.0	56.5

STATION	AVERAGE MAXIMUM MONTHLY TEMPERATURE												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
TEXAS (Cont'd.)													
Dallas	55.3	59.5	68.1	76.6	83.5	91.5	95.4	96.1	89.2	79.6	66.3	57.8	76.6
Eastland	56.2	60.6	68.6	77.7	83.6	92.0	96 4	97.5	89.4	80.1	67.7	59.2	77.4
Fort Worth	54.9	59.4	67.3	76.3	83.0	91.1	95.0	96.3	88.6	79.0	66.2	57.6	76.2
Gainesville	55.5	61.0	69.6	78.0	84.3	92.6	97.1	98.2	91.2	80.9	67.7	58.3	77.9
Galveston	60.4	63.5	67.8	74.6	81.4	87.0	88.7	89.1	86.2	79.9	69.9	63.0	76.0
Greenville	54.1	58.8	66.9	76.2	83.0	91.5	95.9	97.5	90.4	80.6	66.8	57.3	76.6
Huntsville	59.8	63.1	69.6	77.2	83.8	90.6	93.1	94.2	88.6	81.2	68.5	61.4	77.6
Liberty	64.4	68.1	73.1	79.8	85.7	91.4	93.9	94.8	90.6	84.1	73.5	66.6	80.5
Luling	61.1	65.8	73.2	80.4	87.5	94 1	96.6	97 5	90.9	83.2	71.0	63.6	80.1
Marshall	57.1	61.7	68.9	77.8	84.3	91.9	95.1	96.5	90.7	81.2	67.3	59.6	77.7
Mexia	56.9	61.2	68.4	76.7	83.0	90.8	94.9	97.1	90.9	82.0	68.6	60.1	77.6
Nacogdoches	57.3	61.6	68.0	75.3	81.6	88.9	92 2	93 8	88.5	80.1	67.3	59.5	76 2
Palestine	57 2	61.4	67.8	75.8	82.1	89.2	92.0	93.3	87.4	79.3	67.2	59.5	76.0
Paris	53.1	57.3	65.2	74 6	81.4	90.2	94.2	95 4	88.7	78.8	64.8	56.1	75.0
Port Arthur	61.7	65.1	69.8	76.8	83.1	88.8	90 7	91.3	87.5	81.4	70.0	63.7	77.5
San Antonio	60.9	65 9	73.2	80.1	86.6	92.1	95.1	95.5	89.9	82.7	71 2	64.3	79.8
Sealy	61 7	66.1	71.5	80.0	86.3	92.2	94.1	95.9	90.1	83.3	72.2	64.8	79.8
Victoria	64.1	68.0	73.4	79.1	85.4	91 0	92.8	93 8	89.3	83.8	73.4	65.7	80.0
Waco	57.1	61.5	68.6	77.1	84.8	92.1	95.4	95.8	89.4	80.1	68.6	60.1	77.6
Wichita Falls	51.7	57.1	64.9	74.3	81.3	90.3	94.8	95 4	87.2	76 1	62.7	54.2	74.2
VIRGINIA													
Cape Henry	49.4	49.6	56.8	64.2	73.2	81.6	84.8	83.0	78.8	69.2	59.4	50.8	66.7
Charlottesville	45.6	48.1	56.9	67 2	77.0	84 3	87.4	85.9	80.1	69.7	57.9	47.4	67.3
Clarksville	49.9	52.8	61.2	70.6	79.9	87 3	88.7	87.7	82.6	72.2	61 6	50.6	70.4
Danville	51.0	53.3	61.8	71.6	80.2	88.2	90.1	88.8	83.7	73.4	61.9	51.8	71.3
Fredericksburg	47.6	50.0	59.2	68.5	77.4	84.8	87.7	85.8	80.7	70.9	60 3	49.1	68.5
Hot Springs	41.6	43.8	52.2	63.2	72.2	78.4	80.6	78.5	73.4	63.8	51.8	42.8	61.8
Lynchburg	46.6	48.9	57.1	66.9	76.4	83.4	86.1	84.1	79.2	69.1	57.3	47.8	66.9
Norfolk	50.0	50.9	59.2	66.2	75.4	84.1	86.0	84.6	79.9	70 0	60.2	51.1	68.1
Richmond	48.1	50.3	59.2	68.3	77.7	85.4	87.8	86.3	80.9	70.4	59.6	49.4	68.6
Roanoke	46.6	48.7	56.8	67.1	76.6	84.2	86.8	85.1	80.3	69.8	57.0	47.7	67.2
Wytheville	44.7	46.1	54.0	63.9	72 6	79.9	82.1	81.1	76 5	66.4	53.8	45.1	63.8
WEST VIRGINIA													
Bayard	40.0	41.0	49.4	60.3	70.4	77.8	80.7	79.4	74.3	63.6	50.7	40.7	60.7
Charleston	46.3	48.7	56.6	68.2	77.0	84.5	87.3	85.5	81.4	70.6	56.6	47.5	67.5
Gary	46.5	48.3	56.0	67.0	75.4	82.7	84.8	84.1	80.1	69.6	57.3	47.7	66.6
Huntington	48.0	49.6	59.3	70.3	78.6	86.2	88.6	87.4	83.1	72.2	57.7	48.6	69.1
Elkins	42.8	43.6	51.5	62.5	71.7	79.4	82.5	80.6	76.3	65.1	52.4	43.4	62.7
Mannington	43.2	44.6	54.2	65.3	74.3	81.3	83.9	82.0	77.0	67.2	54.1	43.7	64.2
Martinsburg	42.1	43.9	53.7	64.7	76.1	84.7	89.0	86.5	79.8	68.1	55.0	43.3	65.6
Parkersburg	42.7	44.2	53.6	64.9	74.7	83.0	86.2	84.3	79.2	67.9	53.9	44.0	64.9
Pickens	40.6	42.7	51.0	61.0	70.6	77.8	80.3	78.1	74.3	63.5	50.7	42.3	61.1
Union	45.8	47.6	55.8	67.2	76.0	82.6	85.0	83.7	80.2	69.5	55.7	46.1	66.3
DIST. OF COLUMBIA													
Washington	43.8	45.3	54.5	64.5	74.5	82.5	86.1	83.7	78.2	67.4	56.1	45.4	65.2

STATION	AVERAGE MINIMUM MONTHLY TEMPERATURE												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
TEXAS (Cont'd.)													
Dallas	36.0	40.0	46.7	56.0	63.9	72.3	75.6	75.5	68.6	57.9	45.3	38.7	56.4
Eastland	30.8	34.9	41.7	51.0	59.5	67.7	70.6	70.3	63.4	52.8	40.4	34.0	51.4
Fort Worth	35.5	39.2	45.7	54.9	62.7	70.9	74.2	74.3	67.8	57.6	45.0	38.0	55.5
Gainesville	31.4	36.6	41.8	51.2	59.7	68.0	71.4	71.1	64.3	53.0	40.9	34.3	51.9
Galveston	48.2	51.1	55.7	63.5	70.4	76.5	77.9	78.2	74.6	67.6	56.9	50.0	64.2
Greenville	32.6	35.1	42.9	52.9	61.1	69.6	72.7	72.6	65.7	54.4	42.0	35.2	53.1
Huntsville	41.0	44.0	49.1	57.5	64.6	71.1	73.0	72.7	67.8	58.7	48.1	42.8	57.5
Liberty	43.0	46.2	50.9	57.9	64.2	70.3	73.0	71.5	67.5	57.9	47.9	44.0	57.9
Luling	40.3	44.1	49.3	57.5	65.3	71.8	73.5	73.4	68.8	59.5	48.7	42.5	57.9
Marshall	37.6	40.9	46.3	54.3	62.0	69.4	72.2	71.8	66.4	55.8	44.9	39.8	55.1
Mexia	35.9	39.5	45.2	54.4	62.5	69.5	72.3	72.2	66.9	56.6	44.8	38.2	54.8
Nacogdoches	38.8	42.2	47.0	54.7	61.6	68.8	71.1	70.6	65.8	55.5	45.1	40.4	55.1
Palestine	39.6	43.1	48.4	56.6	63.6	70.7	73.0	72.9	67.9	58.6	47.8	42.0	57.0
Paris	32.5	36.3	42.4	52.4	60.6	69.2	72.2	71.9	65.1	54.3	42.2	35.4	52.9
Port Arthur	44.0	46.8	50.8	58.9	65.6	71.4	72.6	72.2	68.3	59.5	48.6	44.0	58.6
San Antonio	40.3	44.2	49.6	57.5	65.4	71.9	73.2	73.0	68.8	59.9	48.4	41.9	57.8
Sealy	44.0	47.8	52.0	60.2	66.5	72.0	73.7	73.5	69.1	61.3	51.3	46.2	59.8
Victoria	46.2	49.8	54.4	62.0	69.3	75.2	76.8	76.7	72.3	63.4	54.1	47.8	62.3
Waco	37.5	41.9	48.2	56.4	64.2	71.5	74.6	75.1	68.4	58.7	47.0	40.2	57.0
Wichita Falls	29.4	34.5	41.1	50.9	59.6	68.8	72.7	73.0	65.5	54.4	40.7	33.4	52.0
VIRGINIA													
Cape Henry	35.5	35.0	40.6	48.0	57.7	66.8	70.6	69.8	67.1	56.4	46.2	37.4	52.6
Charlottesville	28.0	28.8	35.8	44.5	54.6	63.1	66.6	65.3	60.0	48.8	38.8	29.9	47.0
Clarksville	27.9	28.5	35.5	43.3	53.4	62.7	66.7	65.1	59.5	45.0	34.5	27.9	45.8
Danville	31.1	31.8	37.9	46.2	55.1	64.1	67.9	66.3	61.1	47.7	38.5	31.4	48.3
Fredericksburg	26.9	27.5	34.2	42.2	52.3	61.6	66.1	64.1	58.7	45.9	36.4	28.0	45.3
Hot Springs	23.2	23.3	29.7	37.8	46.7	55.4	59.1	57.9	52.7	40.6	31.5	24.6	40.2
Lynchburg	28.7	29.5	35.7	44.0	53.5	62.2	65.9	64.2	58.4	46.4	37.2	30.0	46.3
Norfolk	33.0	33.1	38.9	46.4	56.4	65.2	68.9	68.1	64.0	52.4	42.5	34.4	50.3
Richmond	28.4	29.0	35.8	43.8	53.9	63.1	67.2	65.4	59.7	47.2	37.2	29.5	46.7
Roanoke	29.2	29.6	35.7	43.9	52.8	61.1	65.0	63.5	57.8	46.0	36.8	30.2	46.0
Wytheville	27.3	27.6	33.3	41.3	49.5	57.8	61.3	60.0	54.7	43.0	34.1	27.7	43.1
WEST VIRGINIA													
Bayard	18.9	18.5	24.2	32.2	40.9	50.0	53.0	51.3	45.8	34.6	27.5	20.1	34.8
Charleston	26.5	27.7	33.1	41.8	50.3	59.5	63.5	61.7	55.7	44.2	35.0	28.6	44.0
Gary	25.3	25.5	31.2	40.4	49.4	58.5	62.3	61.1	55.2	41.7	32.1	26.1	42.4
Huntington	28.0	28.3	35.0	44.2	52.8	62.0	65.2	63.4	57.9	46.2	35.7	29.6	45.7
Elkins	21.5	21.4	27.1	35.6	44.6	53.6	57.4	55.8	49.7	38.3	29.2	22.3	38.0
Mannington	22.9	23.0	29.2	37.0	46.5	56.4	59.8	58.4	52.3	39.9	31.2	24.1	40.1
Martinsburg	23.5	23.8	31.0	39.6	50.3	59.8	64.1	61.9	55.0	42.6	33.8	25.6	42.6
Parkersburg	26.1	26.8	33.6	42.6	52.2	61.7	65.1	63.6	57.5	45.8	36.0	28.1	44.9
Pickens	19.4	19.8	25.8	33.7	43.0	51.2	54.3	52.7	48.2	37.0	27.9	20.7	36.1
Union	22.9	23.3	28.9	37.3	45.6	55.0	58.8	56.9	51.2	38.7	29.9	23.4	39.3
DIST. OF COLUMBIA													
Washington	28.5	28.8	36.0	44.2	54.8	64.3	68.4	67.0	61.0	48.9	39.3	30.6	47.7

FROST-FREE PERIOD FOR SELECTED STATIONS IN AND NEAR THE SOUTHERN PINE REGION

Table 3.

STATION	MAP NO.	COUNTY	LAST FROST IN SPRING	FIRST FROST IN FALL	AVG. LENGTH FROST-FREE SEASON
			AVG. DATE	AVG. DATE	DAYS
ALABAMA					
Anniston	69	Calhoun	March 26	Nov. 7	226
Auburn	64	Lee	March 22	Nov. 14	237
Birmingham	68	Jefferson	March 16	Nov. 10	239
Greensboro	66	Hale	March 12	Nov. 13	246
Mobile	61	Mobile	Feb. 16	Dec. 7	274
Montgomery	65	Montgomery	March 3	Nov. 19	261
St. Bernard	70	Cullman	April 8	Oct. 24	199
Thomasville	62	Clarke	March 18	Nov. 10	237
Troy	63	Pike	March 15	Nov. 17	247
Tuscaloosa	67	Tuscaloosa	March 23	Nov. 9	231
ARKANSAS					
Bee Branch	166	Van Buren	April 4	Oct. 29	208
Camden	94	Ouachita	March 25	Nov. 8	229
Fort Smith	164	Sebastian	March 21	Nov. 10	234
Gravette	163	Benton	April 19	Oct. 22	186
Hope	95	Hempstead	March 21	Nov. 7	231
Hot Springs	172	Garland	March 30	Nov. 6	221
Little Rock	171	Pulaski	March 17	Nov. 13	241
Lutherville	165	Johnson	April 3	Oct. 31	211
Mammoth Spring	161	Fulton	April 8	Oct. 22	197
Mariana	169	Lee	March 23	Nov. 3	225
Marked Tree	168	Poinsett	March 27	Dec. 4	222
Mena	173	Polk	March 26	Nov. 8	227
Mountain Home	162	Baxter	April 4	Oct. 26	205
Newport	167	Jackson	March 26	Oct. 31	219
Portland	93	Ashley	March 22	Nov. 5	228
Stuttgart	170	Arkansas	March 28	Oct. 30	216
Texarkana	96	Miller	March 21	Nov. 9	233
DELAWARE					
Dover	1	Kent	April 19	Oct. 24	188
Millsboro	4	Sussex	April 21	Oct. 21	183
Wilmington	104	New Castle	April 17	Oct. 22	187
DIST. OF COLUMBIA					
Washington	8		April 10	Oct. 27	200
FLORIDA					
Apalachicola	58	Franklin	Feb. 11	Dec. 13	305
Avon Park	203	Highlands	Jan. 12	Dec. 25	347
Daytona Beach	54	Volusia	Jan. 21	Dec. 24	337
De Funiak Springs	59	Walton	March 2	Nov. 24	267
Fort Myers	205	Lee			365
Gainesville	55	Alachua	Feb. 22	Dec. 4	285
Jacksonville	56	Duval	Feb. 15	Dec. 11	299
Melbourne	202	Brevard	Jan. 29	Dec. 20	329
Miami	207	Dade			365
Orlando	53	Orange	Feb. 3	Dec. 14	314
Pensacola	60	Escambia	Feb. 20	Dec. 9	292
St. Petersburg	204	Pinellas	Jan. 5	Dec. 29	363
Tallahassee	57	Leon	Feb. 25	Dec. 4	282
Tampa	52	Hillsborough	Jan. 13	Dec. 27	348
West Palm Beach	206	Palm Beach			365
GEORGIA					
Alapaha	47	Berrien	March 10	Nov. 17	252
Albany	48	Dougherty	March 12	Nov. 16	249
Athens	39	Clarke	April 2	Nov. 5	217
Atlanta	42	Fulton	March 24	Nov. 13	233
Augusta	37	Richmond	March 13	Nov. 14	247
Brooklet	36	Bullock	March 15	Nov. 15	245
Brunswick	45	Glynn	Feb. 23	Dec. 1	282
Columbus	49	Muscogee	March 12	Nov. 16	249
Dublin	44	Laurens	March 17	Nov. 11	239
Gainesville	41	Hall	April 1	Oct. 31	213
Hartwell	40	Hart	April 2	Nov. 2	214
Macon	43	Bibb	March 15	Nov. 16	246
Rome	50	Floyd	March 31	Nov. 3	217
Savannah	35	Chatham	Feb. 26	Nov. 26	273
Warrenton	38	Warren	March 24	Nov. 10	231
Waycross	46	Ware	March 9	Nov. 18	254
ILLINOIS					
Cairo	148	Alexander	March 29	Nov. 1	217
INDIANA					
Evansville	147	Vanderburgh	April 3	Oct. 30	210
Paoli	146	Orange	April 25	Oct. 16	174
KENTUCKY					
Berea College	142	Madison	April 18	Oct. 19	184
Greensburg	137	Green	April 21	Oct. 16	178
Greenville	139	Muhlenburg	April 15	Oct. 20	188
Leitchfield	138	Grayson	April 12	Oct. 21	192
Lexington	143	Fayette	April 19	Oct. 22	185
Louisville	145	Jefferson	April 9	Oct. 24	198
Mayfield	141	Graves	April 7	Oct. 22	198
Maysville	144	Mason	April 21	Oct. 19	181
Princeton	140	Caldwell	April 10	Oct. 23	196
Williamsburg	136	Whitley	April 16	Oct. 21	188
LOUISIANA					
Baton Rouge	86	E. Baton Rouge	Feb. 24	Nov. 20	269
Cheneyville	89	Rapides	March 9	Nov. 11	247
Hammond	85	Tangipahoa	March 11	Nov. 18	255
Lake Charles	88	Calcasieu	Feb. 25	Nov. 26	272
New Orleans	87	Orleans	Feb. 20	Dec. 9	292
Robeline	90	Natchitoches	March 24	Oct. 31	221
Ruston P.T.I.	91	Lincoln	March 16	Nov. 14	243
Shreveport	92	Caddo	March 8	Nov. 15	252
MARYLAND					
Baltimore	107	Baltimore	April 7	Oct. 31	207
Cheltenham	3	Prince Georges	April 18	Oct. 20	185
Crisfield	6	Somerset	April 3	Nov. 13	224
Easton Pol.Brks.	2	Talbot	April 14	Oct. 26	195
Snow Hill	5	Worchester	April 17	Oct. 24	190
Solomons	7	Calvert	April 11	Nov. 7	213

STATION	MAP NO.	COUNTY	LAST FROST IN SPRING	FIRST FROST IN FALL	AVG. LENGTH FROST-FREE SEASON
			AVG. DATE	AVG. DATE	DAYS
MISSISSIPPI					
Booneville	71	Prentiss	March 29	Nov. 2	218
Brookhaven	81	Lincoln	March 16	Nov. 13	242
Clarksdale	73	Coahoma	March 29	Nov. 1	217
Forest	77	Scott	March 23	Nov. 6	228
Hattiesburg	83	Forrest	March 13	Nov. 1	233
Jackson	78	Hinds	March 15	Nov. 11	233
Meridian	76	Lauderdale	March 19	Nov. 8	235
Moorhead	74	Sunflower	March 23	Nov. 4	225
Natchez	80	Adams	March 13	Nov. 13	245
Poplarville	84	Pearl River	March 6	Nov. 25	264
State College	75	Oktibbeha	March 25	Nov. 6	226
Vicksburg	79	Warren	March 8	Nov. 15	252
Water Valley	72	Yalobusha	March 31	Nov. 1	215
Waynesboro	82	Wayne	March 23	Nov. 5	227
MISSOURI					
Clinton	151	Clinton	April 17	Oct. 20	186
Columbia	150	Boone	April 10	Oct. 19	192
Farmington	158	St. Francis	April 15	Oct. 23	190
Kansas City	152	Jackson	April 7	Oct. 28	204
Lebanon	155	Laclede	April 21	Oct. 20	182
Nevada	153	Vernon	April 15	Oct. 18	186
Poplar Bluff	159	Butler	April 10	Oct. 24	197
Rolla Sch. Min.	156	Phelps	April 16	Oct. 24	191
Salem	157	Dent	April 20	Oct. 19	182
Seligman	160	Barry	April 14	Oct. 19	188
Springfield	154	Greene	April 9	Oct. 25	199
St. Louis	149	St. Louis	April 3	Oct. 29	209
NEW JERSEY					
Atlantic City	103	Atlantic	April 10	Nov. 5	209
NORTH CAROLINA					
Albemarle	19	Stanly	April 11	Oct. 27	199
Asheville	124	Buncombe	April 11	Oct. 23	195
Charlotte	26	Mecklenburg	March 24	Nov. 11	228
Durham	17	Durham	April 11	Oct. 28	200
Fayetteville	21	Cumberland	March 28	Nov. 5	222
Goldsboro	22	Wayne	April 1	Nov. 4	217
Hickory	123	Catawba	April 5	Oct. 31	209
Highlands	125	Macon	April 22	Oct. 23	184
Lumberton	25	Robeson	March 27	Nov. 7	225
New Holland	23	Hyde	March 22	Nov. 14	237
Pinehurst	20	Moore	April 2	Nov. 2	214
Raleigh	18	Wake	March 23	Nov. 9	231
Weldon	16	Halifax	April 11	Oct. 27	199
Wilmington	24	New Hanover	March 27	Nov. 15	237
Winston-Salem	122	Forsyth	April 11	Oct. 25	197
OKLAHOMA					
Ada	183	Pontotoc	March 27	Nov. 6	224
Mc Alester	174	Pittsburg	March 27	Nov. 5	223
Marlow	182	Stephens	March 30	Nov. 5	220
Muskogee	176	Muskogee	March 26	Nov. 4	223
Newkirk	179	Kay	April 3	Oct. 31	211
Okemah	175	Okfuskee	March 28	Nov. 9	225
Oklahoma City	180	Oklahoma	March 27	Nov. 6	224
Tulsa	177	Tulsa	March 27	Nov. 3	221
Pawhuska	178	Osage	April 4	Oct. 26	205
Wichita Mt.	181	Comanche	April 10	Oct. 30	203
PENNSYLVANIA					
Harrisburg	106	Dauphin	April 10	Oct. 28	201
Reading	105	Berks	April 16	Oct. 26	193
SOUTH CAROLINA					
Charleston	34	Charleston	March 2	Nov. 30	273
Columbia	32	Lexington	March 17	Nov. 18	246
Florence	31	Florence	March 20	Nov. 11	236
Greenville	28	Greenville	March 27	Nov. 10	228
Heath Springs	30	Lancaster	March 27	Nov. 6	224
Newberry	29	Newberry	March 29	Nov. 5	221
Orangeburg	33	Orangeburg	March 18	Nov. 14	241
Spartanburg	27	Spartanburg	March 29	Nov. 5	221
TENNESSEE					
Chattanooga	51	Hamilton	March 21	Nov. 11	235
Clarksville	133	Montgomery	April 3	Oct. 26	206
Crossville	126	Cumberland	April 18	Oct. 11	176
Jackson	130	Madison	April 6	Oct. 25	202
Knoxville	134	Knox	March 30	Nov. 2	217
Lewisburg	127	Marshall	April 10	Oct. 22	195
Memphis	131	Shelby	March 17	Nov. 10	238
Nashville	128	Davidson	March 30	Oct. 30	214
Rogersville	135	Hawkins	April 18	Oct. 21	186
Union City	132	Obion	April 4	Oct. 26	205
Waynesboro	129	Wayne	April 14	Oct. 20	189
TEXAS					
Austin	194	Travis	March 4	Nov. 25	263
Beeville	200	Bee	Feb. 22	Dec. 2	283
Brownwood	191	Brown	March 25	Nov. 12	232
Corpus Christi	201	Nueces	Jan. 26	Dec. 27	335
Dallas	188	Dallas	March 18	Nov. 17	244
Eastland	190	Eastland	March 26	Nov. 12	231
Fort Worth	189	Tarrant	March 13	Nov. 16	252
Gainesville	185	Cooke	March 27	Nov. 11	226
Galveston	198	Galveston	Jan. 21	Dec. 28	341
Greenville	187	Hunt	March 22	Nov. 12	235
Huntsville	100	Walker	March 11	Nov. 25	262
Liberty	101	Liberty	March 5	Nov. 26	266
Luling	196	Caldwell	March 1	Nov. 26	270
Marshall	97	Harrison	March 17	Nov. 12	240
Mexia	193	Limestone	March 14	Nov. 20	251
Nacogdoches	98	Nacogdoches	March 22	Nov. 13	236
Palestine	99	Anderson	March 7	Nov. 23	261
Paris	186	Lamar	March 20	Nov. 13	238
Port Arthur	102	Jefferson	Jan. 28	Dec. 15	321
San Antonio	195	Bexar	Feb. 24	Dec. 3	282

FROST-FREE PERIOD FOR SELECTED STATIONS IN AND NEAR THE SOUTHERN PINE REGION

Table 3 (Continued)

STATION	MAP NO.	COUNTY	LAST FROST IN SPRING	FIRST FROST IN FALL	AVG LENGTH FROST-FREE SEASON
			AVG DATE	AVG. DATE	DAYS
TEXAS (Cont'd.)					
Sealy	197	Austin	Feb. 23	Dec. 5	284
Victoria	199	Victoria	Feb. 24	Dec. 4	283
Waco	192	McLennan	March 10	Nov. 15	250
Wichita Falls	184	Wichita	March 22	Nov. 14	237
VIRGINIA					
Cape Henry	12	Princess Anne	March 21	Nov. 21	245
Charlottesville	119	Albemarle	April 6	Nov. 5	213
Clarksville	14	Mecklenburg	April 8	Oct. 27	203
Danville	15	Pittsylvania	April 4	Oct. 3	209
Fredericksburg	9	Spottsylvania	April 15	Oct. 25	193
Hot Springs	118	Bath	May 1	Oct. 12	164
Lynchburg	10	Campbell	April 4	Oct. 25	204
Norfolk	13	Norfolk	March 23	Nov. 18	239
Richmond	11	Henrico	March 29	Nov. 2	218

STATION	MAP NO	COUNTY	LAST FROST IN SPRING	FIRST FROST IN FALL	AVG LENGTH FROST-FREE SEASON
			AVG DATE	AVG. DATE	DAYS
VIRGINIA (Cont'd.)					
Roanoke	120	Roanoke	April 15	Oct. 22	190
Wytheville	121	Wythe	April 17	Oct. 16	182
WEST VIRGINIA					
Bayard	109	Grant	May 25	Sept. 21	119
Charleston	113	Kanawha	April 20	Oct. 23	186
Gary	117	McDowell	April 26	Oct. 10	167
Huntington	112	Cabell	April 17	Oct. 20	186
Elkins	115	Randolph	May 9	Oct. 7	150
Mannington	110	Marion	May 9	Oct. 7	151
Martinsburg	108	Berkeley	April 22	Oct. 16	177
Parkersburg	111	Wood	April 18	Oct. 19	184
Pickens	114	Randolph	May 13	Oct. 3	143
Union	116	Monroe	May 10	Oct. 5	148

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PINE SAWTIMBER STUMPAGE PRICES IN SOUTH CAROLINA, 1948-1954

by

James W. Cruikshank

and Walter C. Anderson

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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PINE SAWTIMBER STUMPAGE PRICES IN SOUTH CAROLINA, 1948 - 1954

By

James W. Cruikshank and Walter C. Anderson
Division of Forest Economics Research

INTRODUCTION

The three-fold purpose of this paper is to show the kind of stumpage price information that is presently available at the State Forester's office, to demonstrate how it can be analyzed to be made useful, and to recommend ways of increasing the availability and improving the quality of this information. South Carolina was selected for this study as an example of all southeastern states.

Both stumpage prices for a series of years and current stumpage prices are needed. Among ways a series of annual stumpage prices can be used are to analyze long-term price behavior and to forecast prices. A knowledge of current stumpage prices is needed by growers offering timber for sale. They know little about stumpage prices because they sell their timber in an unorganized market where there is no established price, and they have little opportunity to become familiar with stumpage prices through experience since they negotiate only a few sales during their lifetime. Suitable stumpage price reports that would satisfy either of these needs are lacking.

The prices analyzed in this paper were from reports by service foresters to the South Carolina Commission of Forestry. Service foresters operate under the Cooperative Forest Management Act of 1950. One service they perform is to mark timber for cutting. For a portion of the tracts marked, they report the price received by the timber seller. About 1500 timber tracts throughout the state were marked for sale between 1948 and 1954. From reports of these sales, 382 usable records were obtained.

Prices reported by service foresters were chosen because they can be more readily analyzed than prices reported by other sources. Since a tally is kept of timber marked on every tract, it is possible to relate price to various stand characteristics. Also, in general, the price received in each sale was the price a timber seller should get if he sold his timber the way foresters advise it should be sold. Each seller knew the volume of timber he was offering for sale, and his tract was marked according to accepted forestry practices.

This paper is restricted to an analysis of prices received by small, private timber growers for sales of marked, pure pine sawtimber stumpage. At the present time, yellow pine is the species of principal interest to timber buyers and sellers alike. Of all the stands marked for sale by service foresters from 1948 through 1954, approximately three-fifths were pine stands; and two-fifths were mixed pine-hardwood stands.

STUMPAGE PRICES BY YEARS

Prices for the State

The average annual price paid per thousand board-feet for marked, pure pine sawtimber stumpage in South Carolina from 1948 through 1954 is shown in table 1. In years when the average price was highest, a greater proportion of sales brought prices in excess of $35 per thousand board-feet. However, the prices received for individual sales do not show any discernible pattern. In some years when the average price was high, all sales took place at relatively high prices. But in other years when the average price was also high, sales took place at a wide range of prices, some as low as those received in years with a low average price.

Table 1.--Average stumpage prices of yellow pine per thousand board-feet Scribner scale, and distribution of sales by price class, 1948-1954

Years	Average price per MBF	Price class		
		Less than $25.00	$25.00 to $35.00	More than $35.00
	Dollars	Percent	Percent	Percent
1948	25.86	37	54	9
1949	23.45	64	28	8
1950	28.44	43	35	22
1951	32.44	21	42	37
1952	35.68	12	38	50
1953	32.39	9	65	26
1954	27.13	45	44	11

Average stumpage prices per thousand board-feet appear lower when expressed in International Scale ($\frac{1}{4}$-inch kerf) and higher in Doyle scale than they do in Scribner (table 2). The Scribner rule is used by service foresters; the Doyle is commonly used by lumbermen. The apparent differences in price among these three rules are due to the fact that International gives the largest scale for average run of log sizes, Scribner somewhat less, and Doyle the least.

Prices by Zones

In order to present average stumpage prices on a more localized basis, South Carolina was divided into three price zones. These zones are shown in figure 1. Throughout the state there was a wide variation in average prices from county to county; there was also a wide variation in the prices received

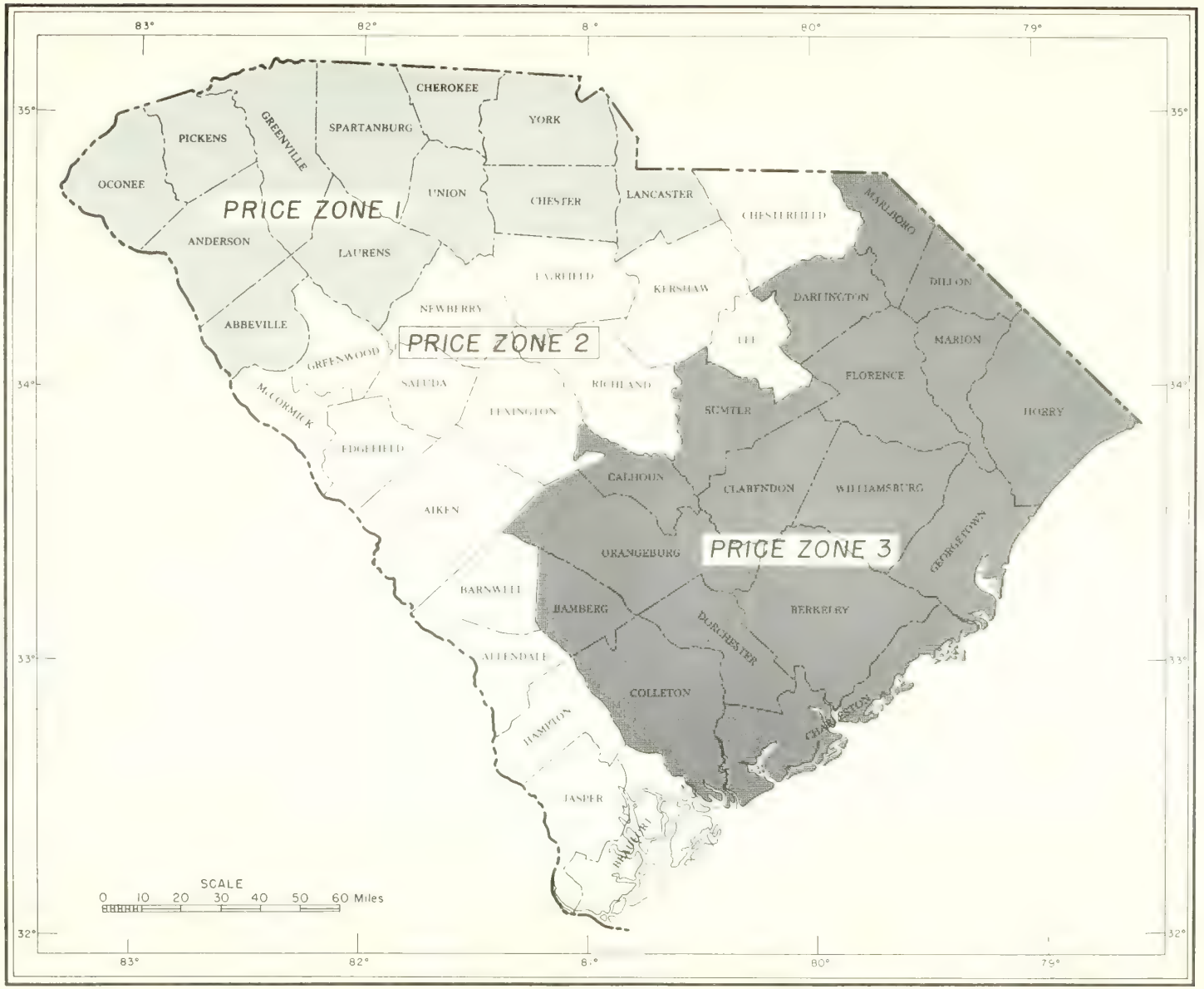


Figure 1.--Stumpage price zones, South Carolina, 1948-1954

for individual sales within each county during a single year. But, on the average, from 1948 to 1954 prices were lowest in the upper piedmont and became progressively higher toward the coast. In this 7-year period, the average price in Price Zone 1 was about five dollars less than that in Price Zone 2, and the Price Zone 3 average price was about five dollars higher than that in Price Zone 2. These differences were statistically significant at the 1-percent level. The average prices in each price zone are shown by log rule in table 3, and the proportion of sales that took place by price class in each price zone is shown in table 4.

Table 2.--Average stumpage prices of yellow pines per thousand board-feet, by log rule, 1948-1954
(In dollars)

Year	Log rule		
	Scribner	International	Doyle
1948	25.86	22.50	35.94
1949	23.45	20.40	32.60
1950	28.44	24.74	39.53
1951	32.44	28.22	45.09
1952	35.68	31.04	49.60
1953	32.39	28.18	45.02
1954	27.13	23.60	37.71

Table 3.--Average stumpage prices of yellow pine per thousand board-feet by price zone and log rule, 1948-1954
(In dollars)

Year	Price Zone 1			Price Zone 2			Price Zone 3		
	Scribner	International	Doyle	Scribner	International	Doyle	Scribner	International	Doyle
1948	22.98	19.76	34.01	23.79	20.94	32.35	27.16	24.17	35.31
1949	20.08	17.27	29.72	20.60	18.13	28.02	26.66	23.73	34.66
1950	20.78	17.87	30.75	24.92	21.93	33.89	33.53	29.84	43.59
1951	23.64	20.33	34.99	32.98	29.02	44.85	38.26	34.05	49.74
1952	30.82	26.50	45.61	34.46	30.32	46.86	40.60	36.13	52.78
1953	26.36	22.67	39.01	36.01	31.69	48.97	35.11	31.25	45.64
1954	20.46	17.60	30.28	27.05	23.80	36.79	34.48	30.69	44.82

Table 4.--Average stumpage prices of yellow pine per thousand board-feet Scribner scale, and proportion of sales by price class in each price zone, 1948-1954

Year	Average price per MBF	Price class		
		Less than $25.00	$25.00 to $35.00	More than $35.00
	Dollars	Percent	Percent	Percent
PRICE ZONE 1				
1948	22.98	50	50	--
1949	20.08	83	--	17
1950	20.78	83	17	--
1951	23.64	61	35	4
1952	30.82	22	56	22
1953	26.36	20	80	--
1954	20.46	92	8	--
PRICE ZONE 2				
1948	23.79	64	27	9
1949	20.60	85	15	--
1950	24.92	54	42	4
1951	32.98	10	52	38
1952	34.46	10	48	42
1953	36.01	6	50	44
1954	27.05	40	50	10
PRICE ZONE 3				
1948	27.16	23	68	9
1949	26.66	42	46	12
1950	33.53	22	36	42
1951	38.26	3	36	61
1952	40.60	8	12	80
1953	35.11	--	58	42
1954	34.48	--	75	25

STUMPAGE PRICES FOR INDIVIDUAL TIMBER TRACTS

The stumpage price received for an individual sale depends upon all the conditions that surround that sale. Some of these conditions can be expressed in terms of measurable factors; others cannot. For each price report obtained, the following information was noted for the marked portion of the stand: Average volume per tree, average volume per acre, total volume, and number of acres. This is not an exhaustive list of possible price determinants, but information about other factors that may have affected price was not available.

Relation of Price to Volume per Tree and Volume per Acre

Each of the four factors presumed to be a determinant of price was tested by using multiple correlation methods. Tests were made for each price zone within the state. In every price zone, average volume per tree and average volume per acre were the only factors, of those tested, found to be correlated with price. The correlation of average volume per tree with price was statistically significant at the 1-percent level, and average volume per acre at the 5-percent level. Together, these two factors accounted for 31 percent of the price variance in Price Zone 1, 23 percent in Price Zone 2, and 16 percent in Price Zone 3.

Estimating Method

The correlation of price with average volume per tree and average volume per acre makes possible a better estimate of the market value of a specific tract than is afforded by the average price in the zone. This better estimate can be made by using table 5.

To illustrate how to estimate the market value of a particular stand, assume that a timber grower in Price Zone 2 has his timber marked for a sale. From the tally given him by the forester who did the marking, the grower knows that the average volume per tree of all marked trees is 184 board-feet, and the average volume marked per acre is 2,988 board-feet. The price ratio for this stand, from table 5, is 1.06. The timber grower may learn from neighbors who recently sold timber or from the forester who marked the stand that timber in the vicinity is averaging $26.50 per thousand board-feet. He finds from the same source that for these other stands the average volume per tree of marked trees was 122 board-feet, and the average volume marked per acre was 2,147 board-feet. The price ratio obtained from table 5 for the average of these other stands is .97. The stumpage price he should receive for his stand when an average price of $26.50 is being paid in the vicinity can be calculated as follows:

$$\frac{\$26.50}{.97} \times 1.06 = \$28.96 \text{ per MBF}$$

If a price reporting service issued average stumpage prices periodically, a timber grower could calculate the price for his stand by simply multiplying the reported price by the price ratio for his stand. For example, assume the average stumpage price reported for Price Zone 2 is $27.50.

Table 5.--Stumpage price ratios per thousand board-feet Scribner scale by average volume per tree of marked trees and average volume marked per acre, 1948 - 1954

PRICE ZONE 1

Average volume per tree (Board-feet)	Average volume marked per acre (board-feet)					
	1,000	2,000	3,000	4,000	5,000	6,000
40	.84	.94	1.04	1.14	1.25	1.35
60	.90	1.00	1.10	1.20	1.31	1.41
80	.96	1.06	1.16	1.26	1.37	1.47
100	1.02	1.12	1.22	1.32	1.43	1.53
120	1.08	1.18	1.28	1.38	1.48	1.59
140	1.14	1.24	1.34	1.44	1.54	1.65
160	1.20	1.30	1.40	1.50	1.60	1.70
180	1.26	1.36	1.46	1.56	1.66	1.76
200	1.32	1.42	1.52	1.62	1.72	1.82

PRICE ZONE 2

40	.86	.88	.90	.92	.94	.96
60	.88	.90	.92	.94	.96	.99
80	.90	.92	.95	.97	.99	1.01
100	.93	.95	.97	.99	1.01	1.03
120	.95	.97	.99	1.01	1.03	1.05
140	.97	.98	1.01	1.03	1.05	1.07
160	.99	1.01	1.03	1.05	1.07	1.10
180	1.01	1.03	1.06	1.08	1.10	1.12
200	1.04	1.06	1.08	1.10	1.12	1.14
220	1.06	1.08	1.10	1.12	1.14	1.16
240	1.08	1.10	1.12	1.14	1.16	1.18
260	1.10	1.12	1.14	1.16	1.19	1.21
280	1.12	1.15	1.17	1.19	1.21	1.23
300	1.15	1.17	1.19	1.21	1.23	1.25

PRICE ZONE 3

40	.86	.89	.92	.94	.97	1.00
60	.87	.90	.93	.96	.98	1.01
80	.88	.91	.94	.97	1.00	1.02
100	.90	.93	.95	.98	1.01	1.04
120	.91	.94	.97	.99	1.02	1.05
140	.92	.95	.98	1.01	1.03	1.06
160	.93	.96	.99	1.02	1.05	1.07
180	.95	.97	1.00	1.03	1.06	1.09
200	.96	.99	1.02	1.04	1.07	1.10
220	.97	1.00	1.03	1.06	1.08	1.11
240	.98	1.01	1.04	1.07	1.10	1.12
260	1.00	1.02	1.05	1.08	1.11	1.14
280	1.01	1.04	1.06	1.09	1.12	1.15
300	1.02	1.05	1.08	1.11	1.13	1.16

This is the average price for the average stand in the zone. In setting up table 5, a price ratio of 1.00 was given the average stand in each zone. Therefore, this ratio can be dropped from the calculation when reported prices are used. In this case the comparative price could be calculated as follows:

$27.50 x 1.06 = $29.15 per MBF

If a price reporting service issued tables showing the stumpage price for various combinations of average volume per tree and average volume per acre, the above computation would not be necessary. Table 6 shows the prices for various combinations in Zone 2. Such a table would enable the timber owner to estimate directly the price applicable to his class of timber.

Table 6.--Stumpage prices per thousand board-feet Scribner scale, by average volume per tree and average volume per acre, Price Zone 2, 1954

Average volume per tree (Board-feet)	Average volume marked per acre (board-feet)				
	1,000	2,000	3,000	4,000	5,000
	Dollars	Dollars	Dollars	Dollars	Dollars
40	23.26	23.80	24.34	24.89	25.43
60	23.80	24.34	24.89	25.43	25.97
80	24.34	24.89	25.70	26.24	26.78
100	25.16	25.70	26.24	26.78	27.32
120	25.70	26.24	26.78	27.32	27.86
140	26.24	26.78	27.32	27.86	28.40
160	26.78	27.32	27.86	28.40	28.94
180	27.32	27.86	28.67	29.21	29.76
200	28.13	28.67	29.21	29.76	30.30
220	28.67	29.21	29.76	30.30	30.84
240	29.21	29.76	30.30	30.84	31.38
260	29.76	30.30	30.84	31.38	32.19
280	30.30	31.11	31.65	32.19	32.73
300	31.11	31.65	32.19	32.73	33.27

Log Scale Converting Factors for Price and Volume

Table 5 makes possible the calculation of stumpage prices in terms of the Scribner rule only. However, bids may be received in terms of the Doyle rule or lumber measure. Therefore, a timber grower must be able to convert stumpage prices from terms of one rule to another. These conversions can be made by using table 7. For example, assume that the timber grower in Price Zone 2

Table 7.--Multipliers for converting stumpage prices or volumes from terms of one log rule to another, by price zone

TO CONVERT PRICES, find given log rule below, read across to price multiplier under desired price zone and log rule.	TO CONVERT VOLUMES, find price zone and given log rule below, read down to volume multiplier opposite desired log rule.											
	Price Zone 1			Price Zone 2			Price Zone 3			South Carolina		
	Scribner	International 1/	Doyle	Scribner	International 1/	Doyle	Scribner	International 1/	Doyle	Scribner	International 1/	Doyle
Scribner	1.00	.86	1.46	1.00	.88	1.36	1.00	.89	1.30	1.00	.87	1.39
International 1/	1.17	1.00	1.72	1.13	1.00	1.53	1.12	1.00	1.45	1.14	1.00	1.58
Doyle	.68	.58	1.00	.74	.65	1.00	.77	.69	1.00	.72	.63	1.00

1/ Can be assumed to be equivalent to lumber tally.

received a bid on his marked timber of $25.00 per thousand board-feet lumber tally. He would want to compare this bid with the price he had previously calculated, which was in terms of Scribner. International scale is assumed to be equivalent to lumber tally. To find the multiplying factor to make this conversion, he reads down the left-hand column of table 7 to the row marked "International," and then reads across to Price Zone 2. In the cell where the International row intersects the Scribner column, he finds the multiplier "1.13." He can then calculate the equivalent Scribner price of this lumber tally bid as follows:

$25.00 x 1.13 = $28.25 per MBF

Volumes can also be converted from one scale to another by using table 7. The timber grower in Price Zone 2 may, for example, wish to convert the average volume marked per acre in his stand from Scribner to Doyle. He finds the multiplier ".74" in table 7 by reading down the Scribner column under Price Zone 2 until it intersects the row marked "Doyle." The board-foot volume Doyle scale equivalent to 2,988 board-feet Scribner scale is calculated as follows:

2,988 x .74 = 2,211 board-feet

PRICE REPORTS

The need to inform small timber growers of current stumpage prices and to accumulate a series of average stumpage prices could be satisfied by a price reporting service. No such service now exists in South Carolina or in any other southeastern state.

Before a price reporting service can function, decisions must be made with regard to: (1) the kinds of price and related data that will be collected, (2) the sources from which these data will be obtained, (3) the amount of data that will be needed, (4) the factors that affect price, and (5) the frequency with which price reports will be issued.

Kinds of Prices to Collect

The ideal stumpage prices to collect for compiling periodic price reports would be those paid to private timber growers for sales of marked and cruised timber that they were not under compulsion to sell. It may be presumed that in such sales buyers and sellers possessed equal knowledge of the volume and quality of timber being sold, unlike lump-sum sales made without a cruise. It may also be assumed that in such sales, buyers and sellers had similar bargaining positions, in contrast to sales forced by the circumstances of the seller where he wished only to get a specific sum of money as quickly as possible. For these reasons, the average prices paid for marked timber are higher than the average prices for all sales. But to receive these higher prices, timber growers would have to sell marked and cruised stands, not only so they would know what they were selling, but because unmarked sales include small and low-quality trees of little value that lower the price paid. The principal objection to reporting average prices for the general run of sales is that they would tend to perpetuate the lower level of prices.

Sources of Prices

The best source of data for a price reporting service would be those foresters who mark stands for private timber growers. They would have an incentive to collect such data because price reports would be useful to them and the people they serve. Service foresters would be the principal suppliers of these data because of the nature of their work and the fact that they are under the direction of the state forester. Consulting foresters and pulp company foresters may also be willing to cooperate. Service foresters and other cooperators might use Form 1 (shown on following page) to record stumpage prices and other related data. The information required in columns 4 through 7 in this form would have to be collected by making a call-back on the landowner; the rest of it could be obtained from the timber marking record. Unless the landowner reported when his timber was sold, it would be difficult to know when to do this. This difficulty is indicated by the fact that service foresters reported stumpage prices for less than one-third of the timber tracts they marked in South Carolina between 1948 and 1954. For this reason, to get enough prices, it may be desirable to supplement prices from private sales with prices from sales of state and national forest stumpage. Prices received in sales of government timber are, on the average, higher than those received in sales of private timber. Tests would show whether or not stumpage prices from all sources could be combined. If so, they would be combined in the form of price indexes. The current average stumpage price could be obtained by using the average combined price index to adjust the average stumpage price paid in a base year.

Number of Individual Prices Required

The number of sales from which prices would be required to get an average price within a specified limit of error can be estimated from the standard errors obtained in this study. These standard errors are shown in table 8.

Table 8.--Standard errors of mean for average stumpage prices per thousand board-feet Scribner scale, by price zone, 1948-1954

Year	Price Zones						South Carolina	
	Price Zone 1		Price Zone 2		Price Zone 3			
	Dollars	Percent	Dollars	Percent	Dollars	Percent	Dollars	Percent
1948	3.00	13.0	1.50	6.3	1.62	6.0	1.11	4.3
1949	3.66	18.2	.96	4.7	1.26	4.7	.93	4.0
1950	1.22	5.9	1.40	5.6	1.34	4.0	1.03	3.6
1951	1.24	5.2	1.67	5.1	1.38	3.6	1.06	3.3
1952	1.95	6.3	1.26	3.6	1.88	4.6	1.05	2.9
1953	.86	3.3	1.96	5.4	1.47	4.2	1.10	3.4
1954	.96	4.7	1.38	5.1	.94	2.7	1.06	3.9

REPORT OF PURE-PINE SAWTIMBER SALES

South Carolina

Period covered: _____ to _____

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
											For office use only		
Price zone (Code)	County	Timber seller	Date of sale	Total price received	Bidders	Product for which purchased	Stand quality	Acres marked and sold	Volume marked and sold	Pine trees marked and sold	Average price received per MBF	Average volume per tree	Average volume per acre
	Code	Code	Mo.-Yr.	Dollars	Number	Code	Code	Number	MBF	Number	Dollars	MBF	MBF

Signature _____

Date _____

Form 1--Sample Report Form for Collecting Stumpage Price Data

In calculating the number of prices required, it was assumed that the same price variance would be obtained in other samples that was obtained in this one. The estimated number of prices required to calculate average prices with an acceptable error of $0.50, $1.00, or $1.50 for each price zone and for the state is shown in table 9. If this number of prices is obtained, the chances will be only 5 out of 100 that the true price and the estimate differ by more than the specified error.

It can be seen from the table that if the acceptable limit of error for the average price was set at $1.50 for each price zone, enough prices would be collected to get a state average within an error of $1.00. In the period 1948 to 1954, an error of $1.50 in the average price would have given a range of errors of 4.9 to 7.5 percent in Price Zone 1, 4.2 to 7.3 percent in Price Zone 2, and 3.4 to 5.6 percent in Price Zone 3. In this same period, an error of $1.00 for the state would have given a range of errors of 2.8 to 4.3 percent.

Table 9.--Number of prices required to estimate average price within acceptable error
(Number of price reports)

Acceptable error 1/ (Dollars)	Price Zone 1	Price Zone 2	Price Zone 3	South Carolina
.50	556	734	795	1,009
1.00	139	184	199	252
1.50	61	82	88	113

1/ Two standard errors.

Factors That Affect Price

The determinants of stumpage prices must be known in order to apply average prices to specific stands. To select these price determinants, stumpage prices and related data from individual sales are needed for analysis. Four factors thought to affect stumpage prices were tested in this study and, as has been shown, two were correlated with price. Other factors which may also be correlated with price were not tested because no information was available about them. Some additional factors that should be tested are type of product, quality of stand, and number of bidders. Product may be a determinant of price since, for example, higher prices are generally paid for stumpage when logs are to be cut for export than when they are to be converted into lumber at a nearby mill. Stand quality was partially taken into account in this study since one indicator of it, average volume per tree, was tested and found to be significant. A better measure of quality would be a classification of the total volume into log or tree grades. The

number of bids received may be the most important factor that was not tested. In sales of farm timber in Georgia, Todd and Zirkle [1] found little or no difference between prices received for 1- and 2-bid sales, but 3- to 6-bid sales brought much higher prices. Also, Guttenberg [2] found that the number of bids received was the factor most highly correlated with stumpage prices paid for national forest timber in East Texas, Louisiana, and Mississippi.

Frequency of Price Reports

Average annual stumpage prices may be adequate for a price series, but timber sellers would probably prefer to have price reports issued semi-annually or quarterly. It would be difficult to issue an average price, based on field reports, more frequenly than once a year. Prices from the same number of sales would be needed to calculate each average price if the same degree of accuracy were required for each report. Not enough sales would take place in any price zone in periods of less than a year to calculate an average price with a high degree of accuracy. Of course, average prices for these intervening periods may be useful even with less accuracy. To increase the number of sales that would take place in each price zone, larger zones could be delineated that extended across state lines. But even if this were done, the shorter the interval the average price represented, the more effort would be required to collect prices for sales that were completed during the interval. This difficulty might be eliminated if timber sellers reported by mail the date their timber was sold and the price they received for it. Also, price reports would have to be issued more speedily if a short interval were used than a longer one, because prices would go out of date more rapidly. This difficulty could perhaps be overcome by correlating stumpage prices with a time series for which reports were issued quarterly or monthly. Prices could then be reported for the intervening quarters on the basis of this other series.

1/ Todd, A. S., Jr., and Zirkle, J. J., Jr. Marketing farm timber in Monroe County, Georgia. Southeastern Forest Expt. Sta. Station Paper 3, 33 pp., illus. 1949.

2/ Guttenberg, S. Southern pine stumpage price analysis. Southern Forest Expt. Sta. Unpublished progress report. 1954.

Agriculture-Asheville

Station Paper No. 58 December 1955

How to Control the Pollination of Slash and Longleaf Pine

by François Mergen, Harry Russell and Kenneth B. Pomeroy

SOUTHEASTERN FOREST EXPERIMENT STATION
Asheville, North Carolina
U. S. Department of Agriculture - Forest Service

The tree improvement research leading to this publication was a cooperative undertaking of Yale University, the Florida Board of Forestry, and the U. S. Forest Service. Dr. François Mergen (formerly Geneticist at the Lake City Research Center) is Assistant Professor of Forest Genetics, Yale University, School of Forestry, John A. Hartford Program in Forest Biology at Valhalla, N. Y. Harry Rossoll, of Region 8, U. S. Forest Service, Atlanta, Georgia, made the illustrative drawings. K. B. Pomeroy is Officer in Charge of the Lake City Research Center.

How to Control the Pollination of Slash and Longleaf Pine

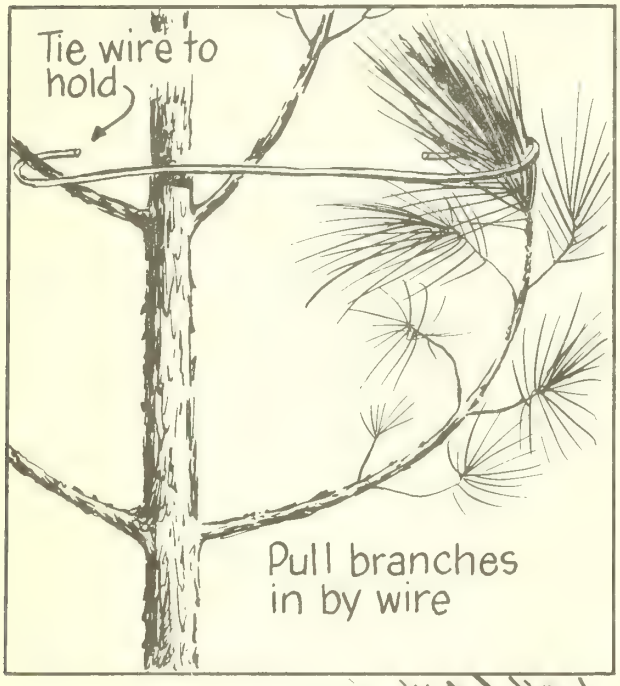
by François Mergen, Harry Rossoll and Kenneth B. Pomeroy

INTRODUCTION

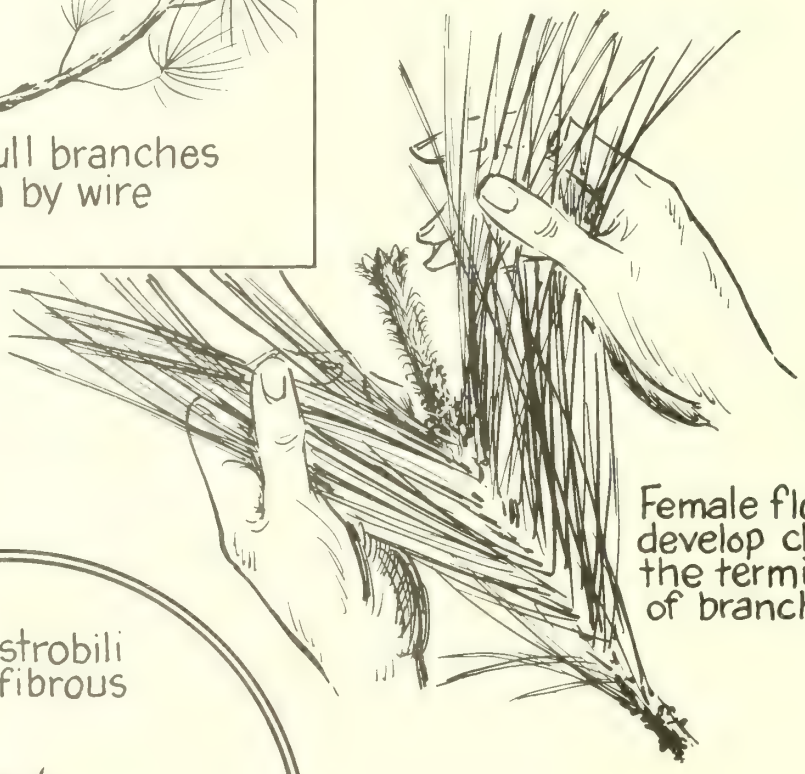
In this outline, detailed instructions are given for controlled pollinations of slash and longleaf pine. The various steps are illustrated with true-to-life drawings. For more than a decade these techniques have been used with good results in the tree improvement program at Lake City, Florida.

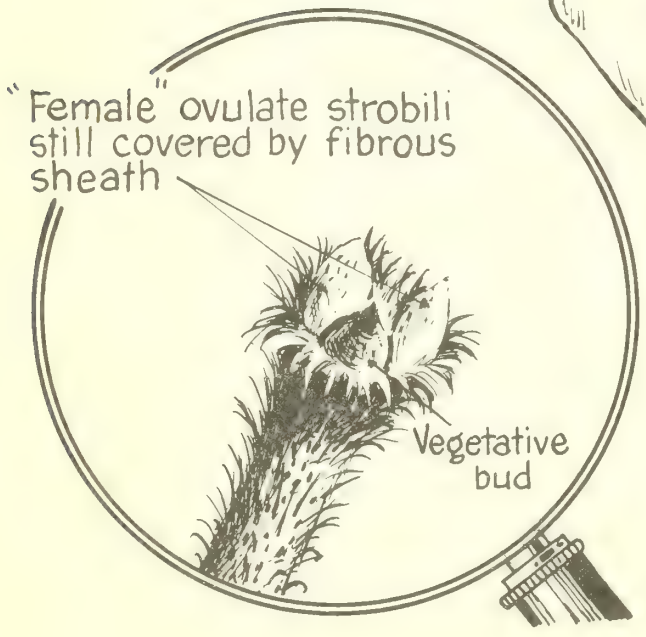
Foresters desiring a more thorough technical discussion are referred to USDA Circular No. 792, "Methods used to control pollination of pines in the Sierra Nevada of California," by W. C. Cummings, and F. I. Righter, published in 1948.

ISOLATION OF FEMALE FLOWERS

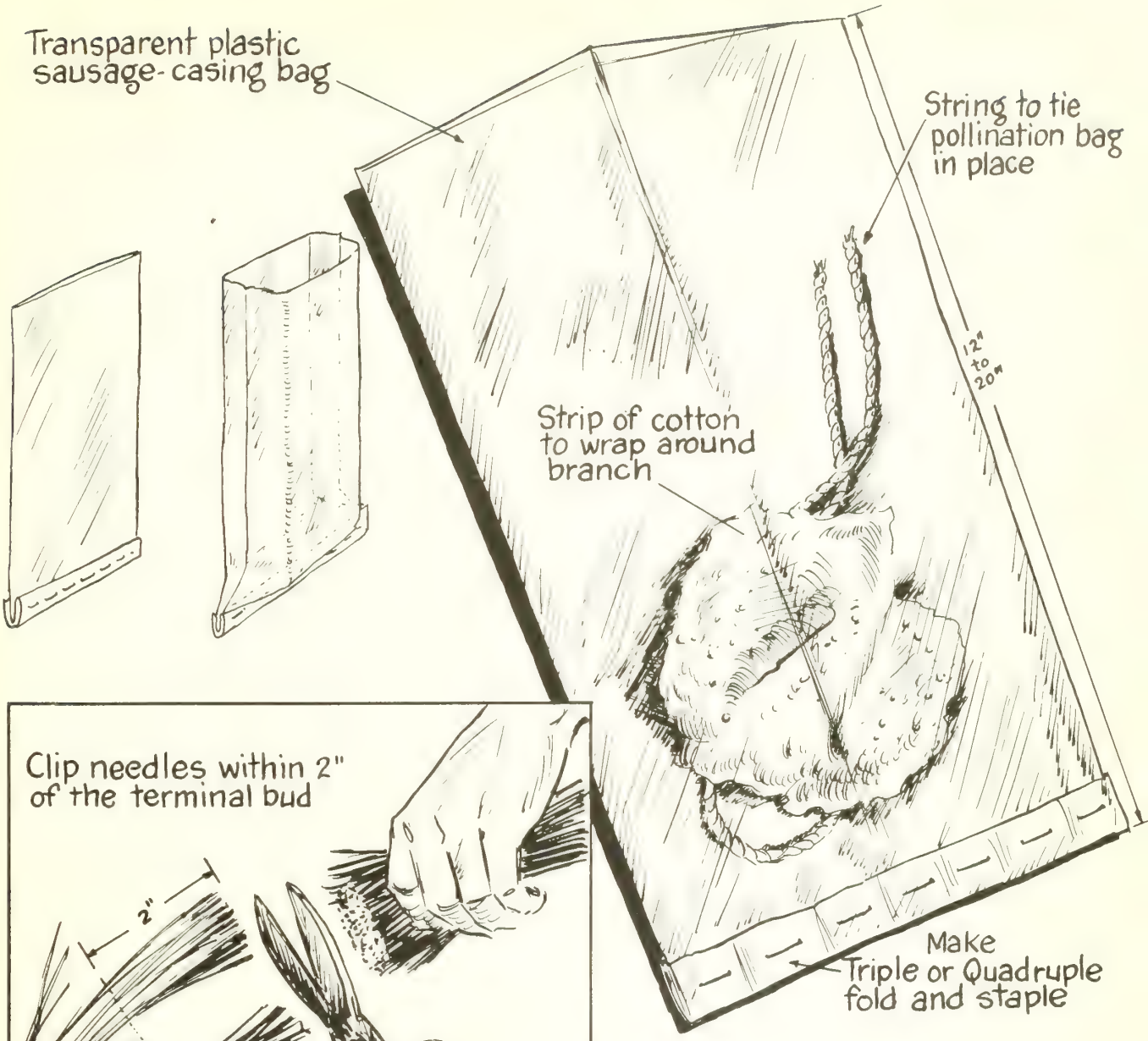


The female flowers or ovulate strobili are born right next to the terminal buds in the upper part of the crown. Slash pine flowers become visible early in January, while those of longleaf pines appear about 2 weeks later. A wire hook is an essential tool for pulling branch tips within "comfortable" working distance.



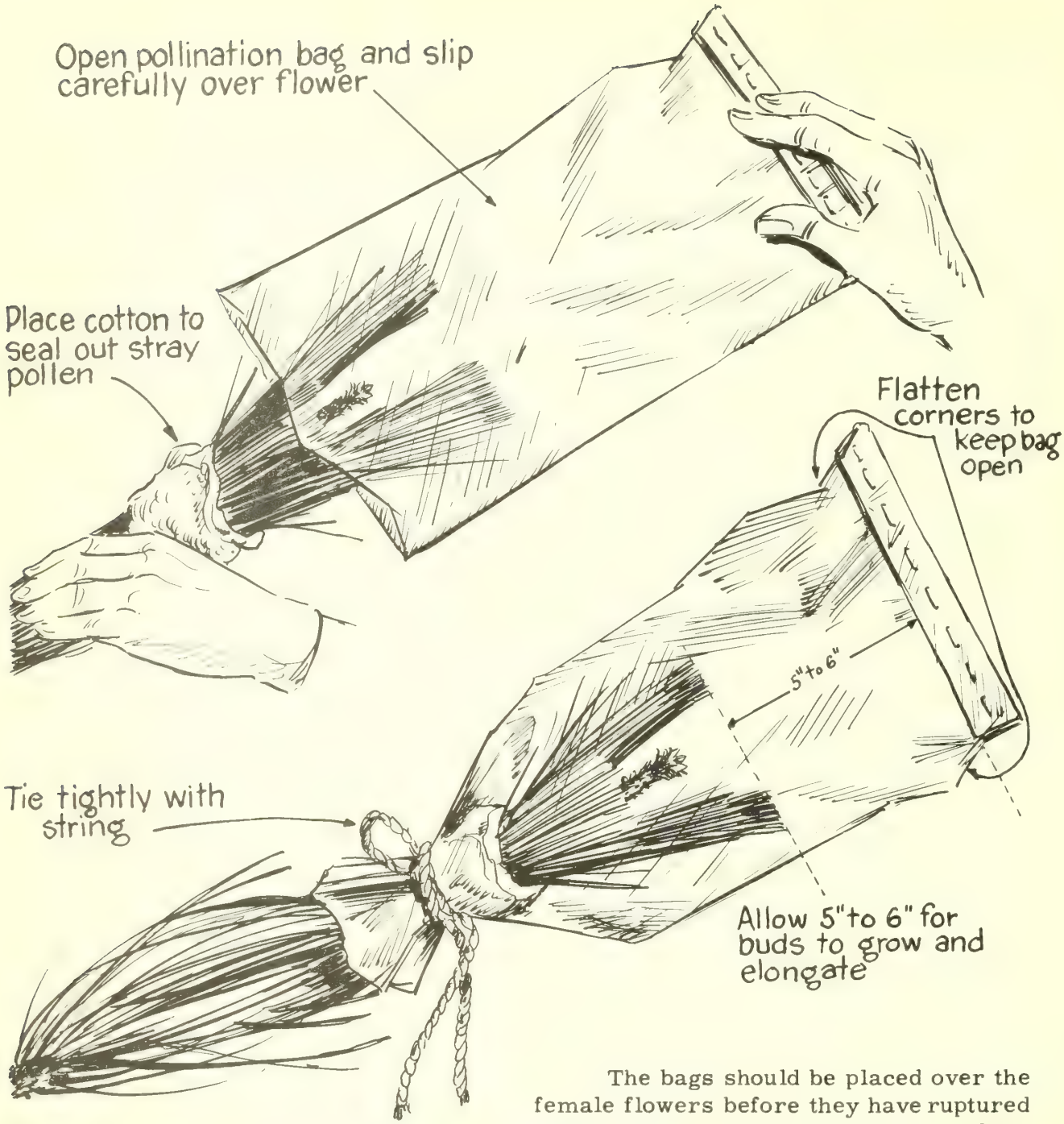


A white fibrous covering encloses the female flowers at the time they push through the thin scales of the "dormant" bud. The flowers appear either singly or in clusters of up to 20 per branch tip.


Transparent plastic sausage-casing bag
String to tie pollination bag in place
12" to 20"
Strip of cotton to wrap around branch
Make Triple or Quadruple fold and staple

Plastic sausage casing is satisfactory for bagging slash and longleaf pine conelets. This type of bag is permeable to water and light, is strong, and inexpensive. The bags should be assembled on the ground; a strip of nonabsorbent cotton, and a piece of string are placed inside the bag to facilitate handling while in tree crowns.

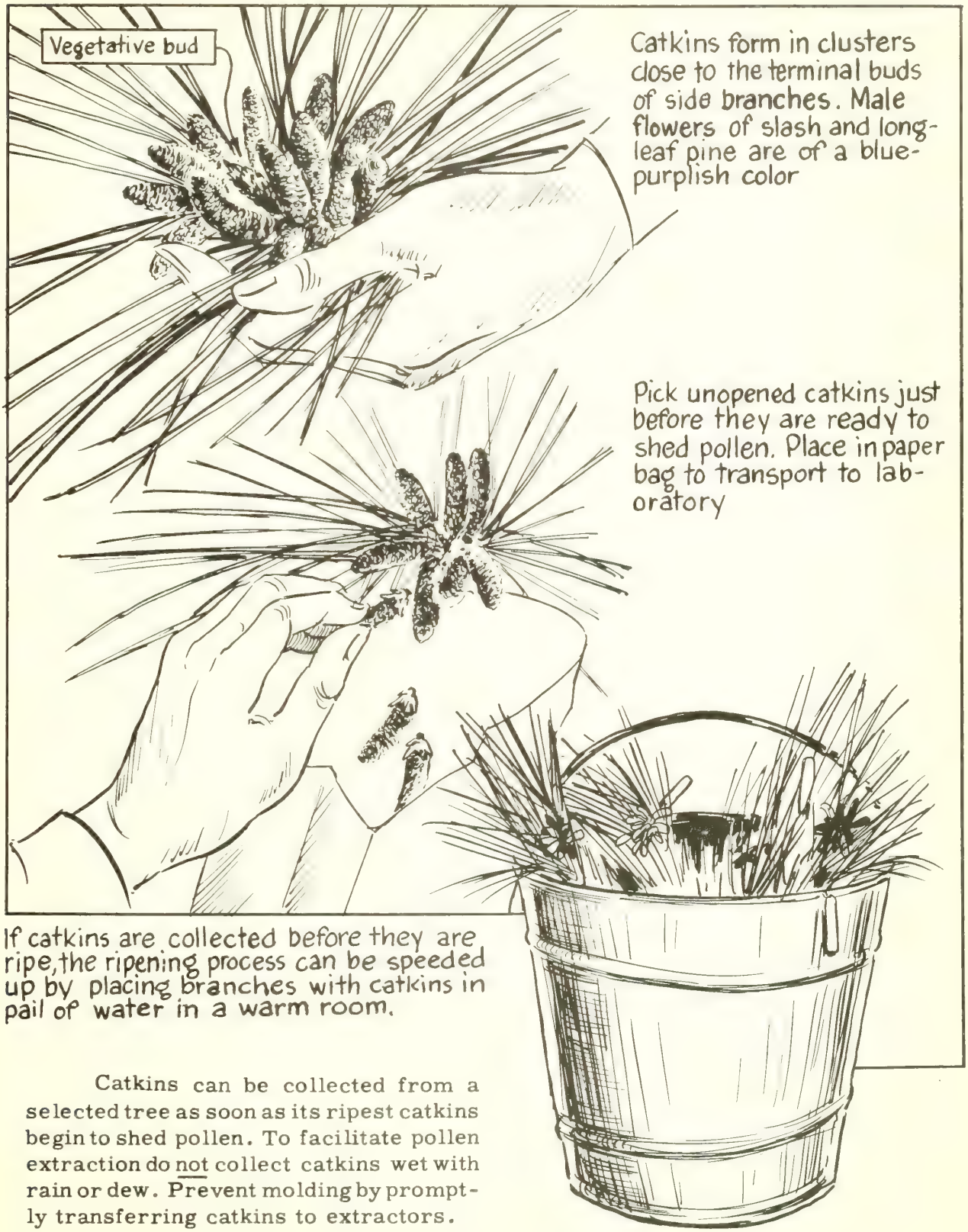
When clipping the needles, a "brush" of needles should be left on each side of the flowers to protect them in case the bag collapses.


Open pollination bag and slip carefully over flower
Place cotton to seal out stray pollen
Flatten corners to keep bag open
5" to 6"
Tie tightly with string
Allow 5" to 6" for buds to grow and elongate

The bags should be placed over the female flowers before they have ruptured the protective sheath and the scales of the conelet (pinkish-white in color) become visible. Before placing bag, check bud for male catkins. These should be twisted off unless selfing is desired. Place bag so that there is adequate space for the elongation of the vegetative bud during spring growth.

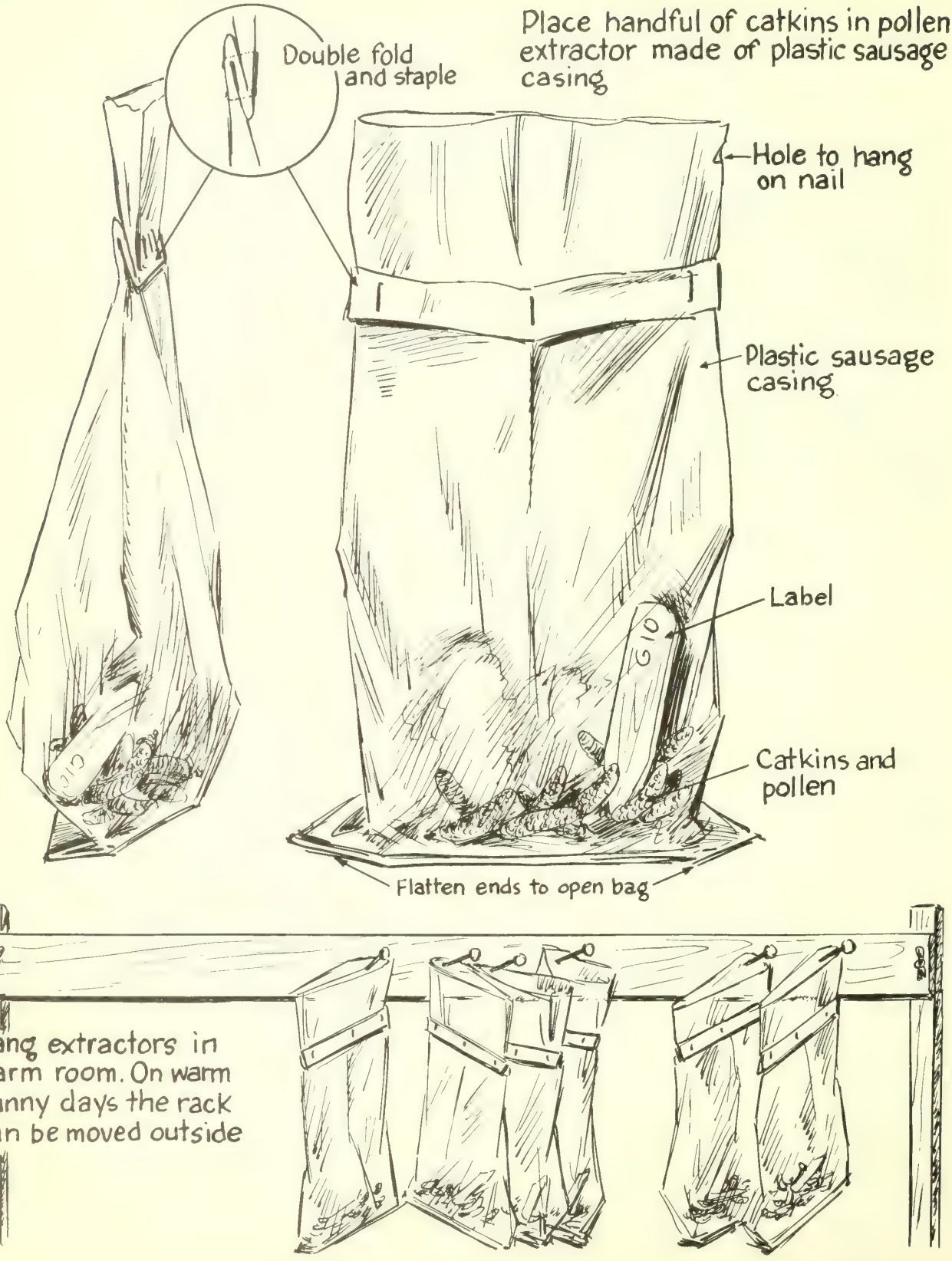
The bags should be tied <u>firmly</u> to the branches with a cotton string, or a combination paper-wire plant "twistem."

COLLECTION OF MALE CATKINS


Vegetative bud
Catkins form in clusters close to the terminal buds of side branches. Male flowers of slash and long-leaf pine are of a blue-purplish color
Pick unopened catkins just before they are ready to shed pollen. Place in paper bag to transport to laboratory
If catkins are collected before they are ripe, the ripening process can be speeded up by placing branches with catkins in pail of water in a warm room.

Catkins can be collected from a selected tree as soon as its ripest catkins begin to shed pollen. To facilitate pollen extraction do not collect catkins wet with rain or dew. Prevent molding by promptly transferring catkins to extractors.

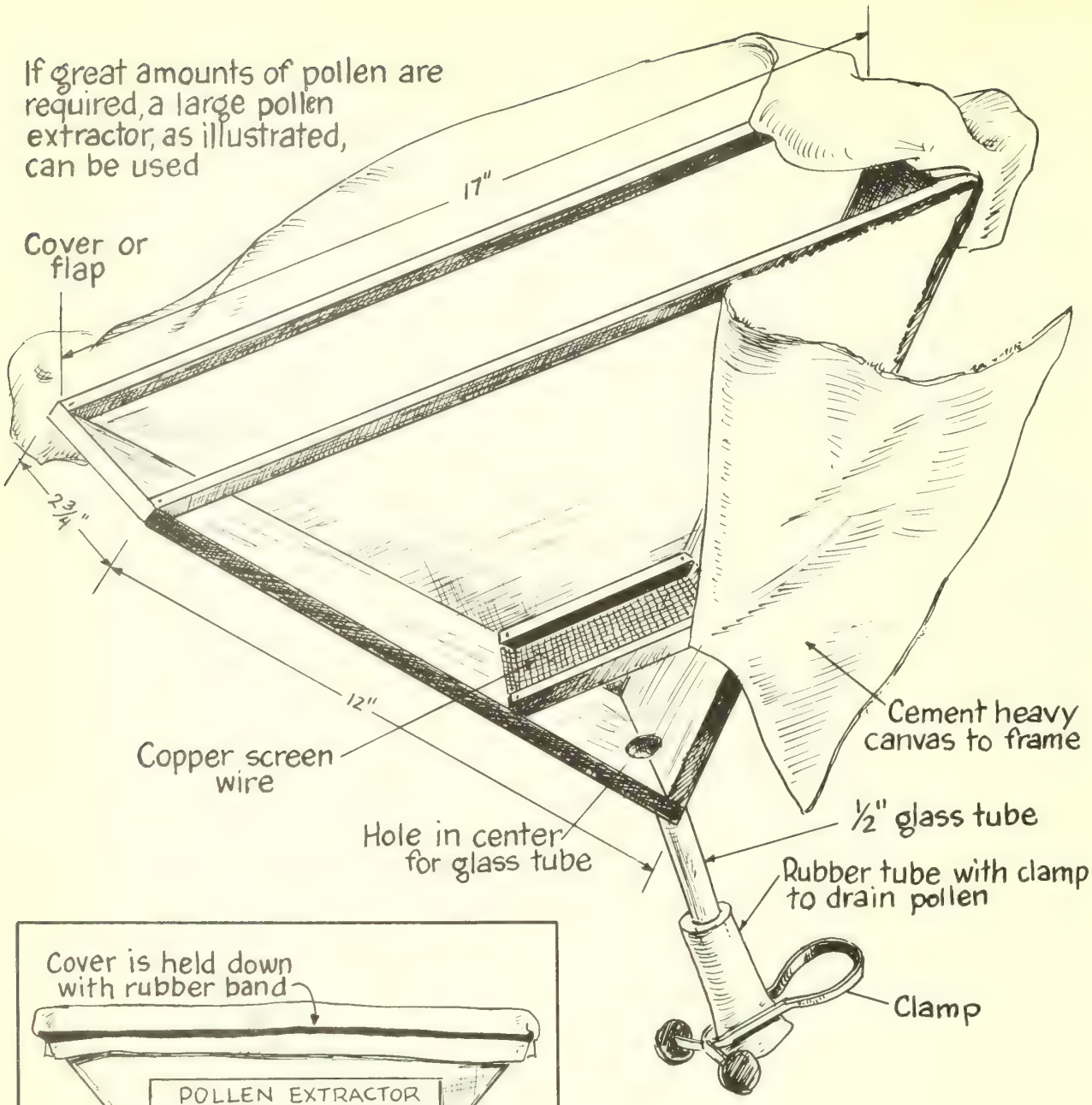
EXTRACTION OF POLLEN

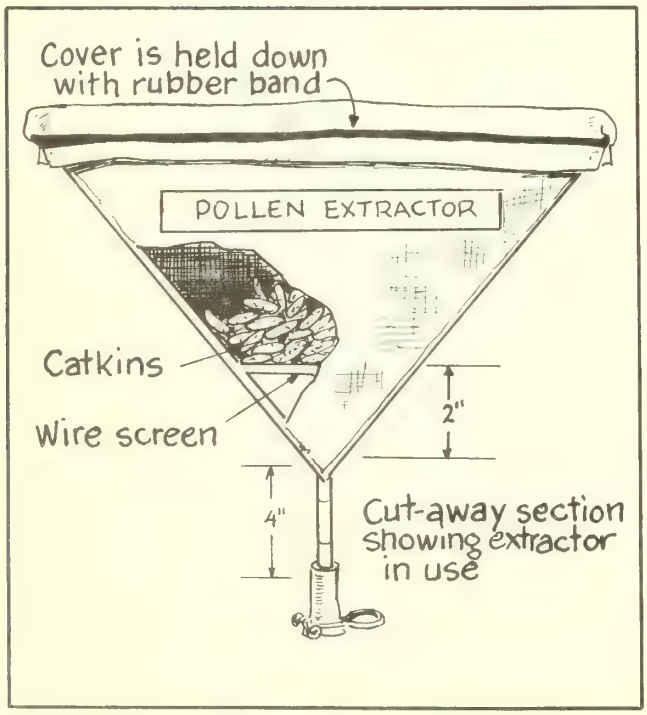

Place handful of catkins in pollen extractor made of plastic sausage casing
Double fold and staple
Hole to hang on nail
Plastic sausage casing
Label
G10
Catkins and pollen
Flatten ends to open bag
Hang extractors in warm room. On warm sunny days the rack can be moved outside

Shake bag vigorously before draining pollen from extractor - then cut bag below fold
Cut below fold
Drain catkins into sieve
Cover
Catkins
60 Mesh screen
Pollen falls to bottom
Pollen settles to bottom - Shake sideways
Pollen free from gross impurities

If only a small amount of pollen is desired, a hole can be punched in the wall of the bag and the pollen strained through it.

A regular soil sieve (60 mesh) is used when a large quantity of pollen is needed. To prevent contamination, the sieves should be sterilized after each use by either washing them in 95 percent alcohol, or by placing them in a hot oven for several minutes. A combination of these two methods is very satisfactory.

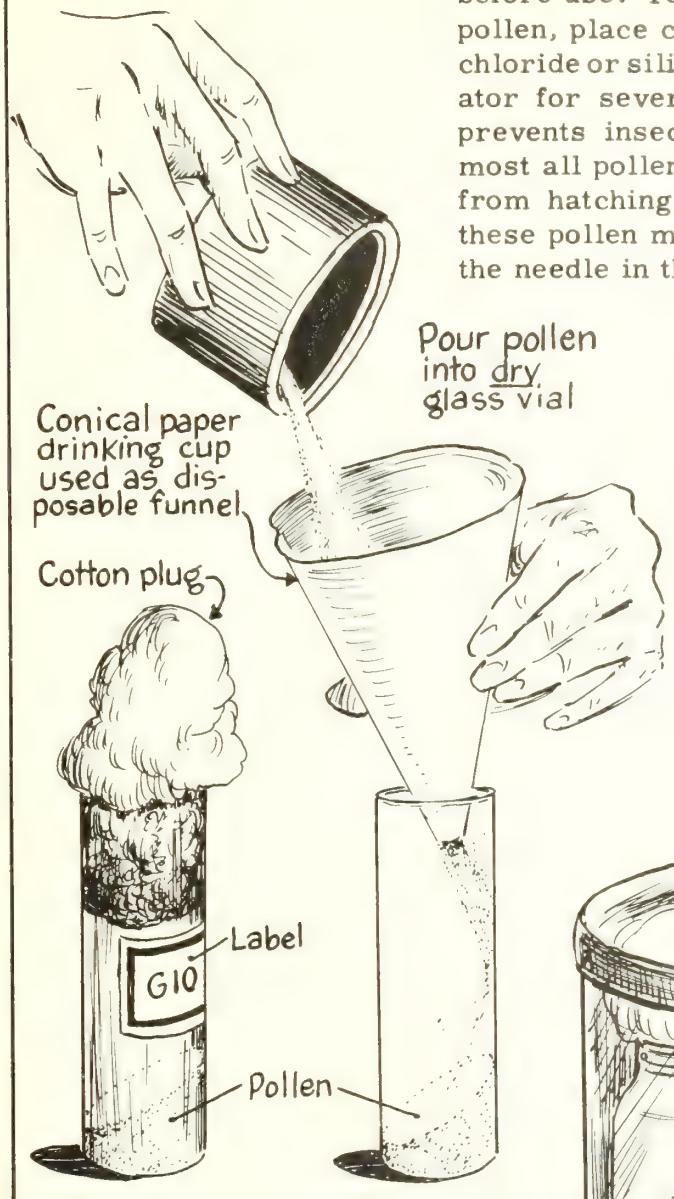

If great amounts of pollen are required, a large pollen extractor, as illustrated, can be used
17"
Cover or flap
2¾"
12"
Copper screen wire
Hole in center for glass tube
Cement heavy canvas to frame
½" glass tube
Rubber tube with clamp to drain pollen
Clamp



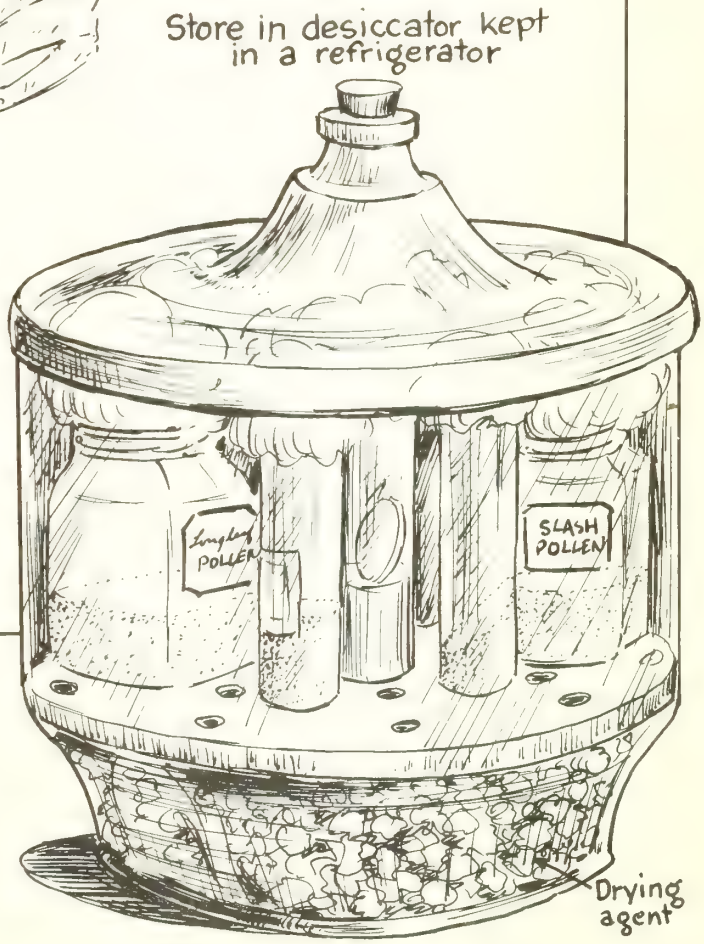
If too large a quantity of catkins is placed in one extractor, poor air circulation will further the growth of mold. Mold will also develop if the catkins were too green or too moist when they were collected.

The extractor should be placed in a warm, dry room (80-90°F.) in which good air circulation is maintained.

The pollen should be handled in a draft-free room. All equipment should be sterilized before use. To prevent molding of extracted pollen, place cotton-stoppered vials in calcium chloride or silica gel desiccator in a refrigerator for several days. This treatment also prevents insect eggs, which are found in almost all pollen lots of slash and longleaf pine, from hatching. Besides injuring the pollen, these pollen maggots have a tendency to clog the needle in the pollinator.



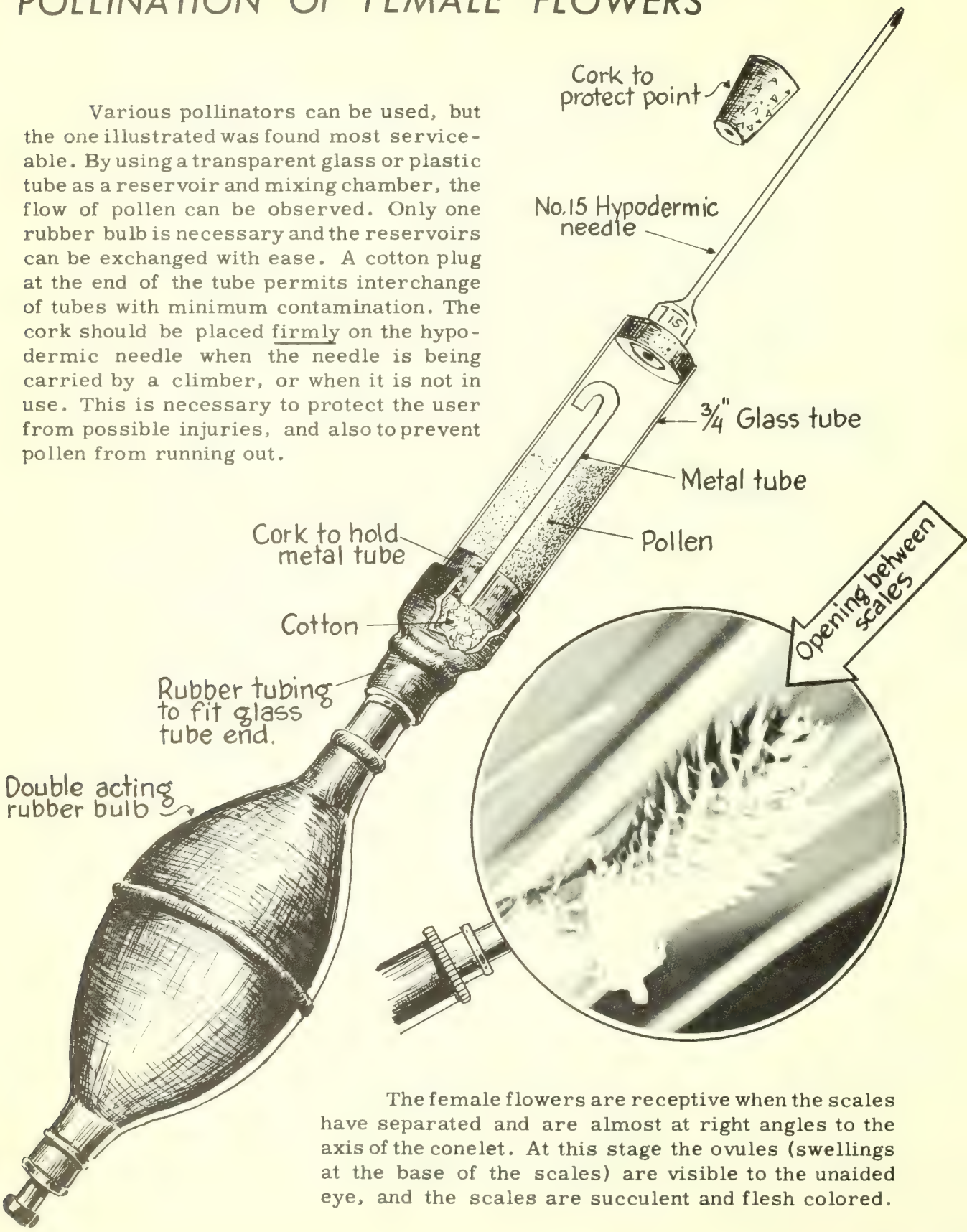
After pollen has been stored at a low temperature, do not open vial until the glass of the container has reached room temperature. This prevents moisture from condensing on inside walls.



Pollen may stay viable for a year when stored at 39°F. at a relative humidity of 30 percent. A relative humidity of approximately 30 percent is obtained by placing an excess of a sulfuric acid solution with a density of 1.45 in the well of a desiccator.

POLLINATION OF FEMALE FLOWERS

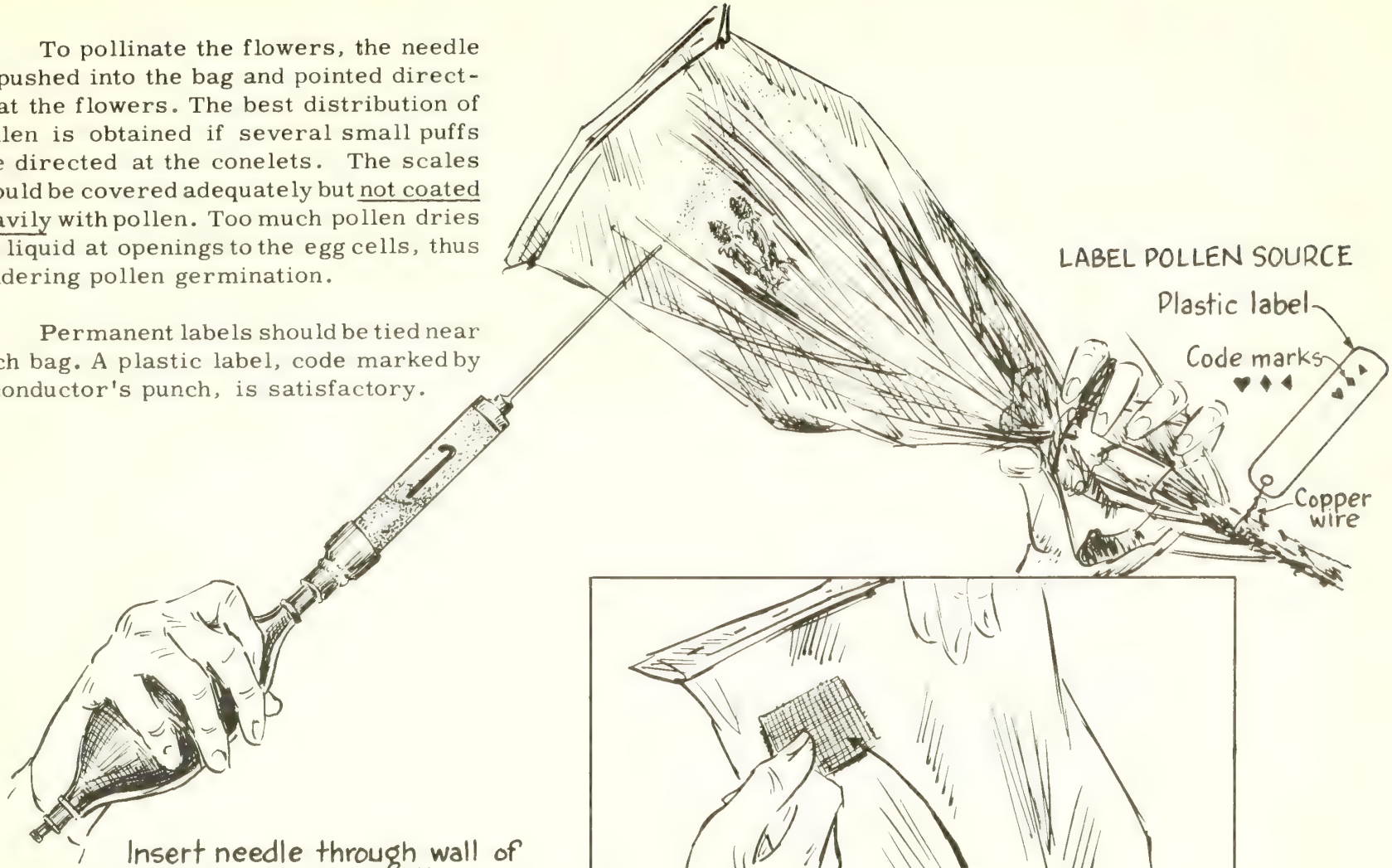
Various pollinators can be used, but the one illustrated was found most serviceable. By using a transparent glass or plastic tube as a reservoir and mixing chamber, the flow of pollen can be observed. Only one rubber bulb is necessary and the reservoirs can be exchanged with ease. A cotton plug at the end of the tube permits interchange of tubes with minimum contamination. The cork should be placed firmly on the hypodermic needle when the needle is being carried by a climber, or when it is not in use. This is necessary to protect the user from possible injuries, and also to prevent pollen from running out.

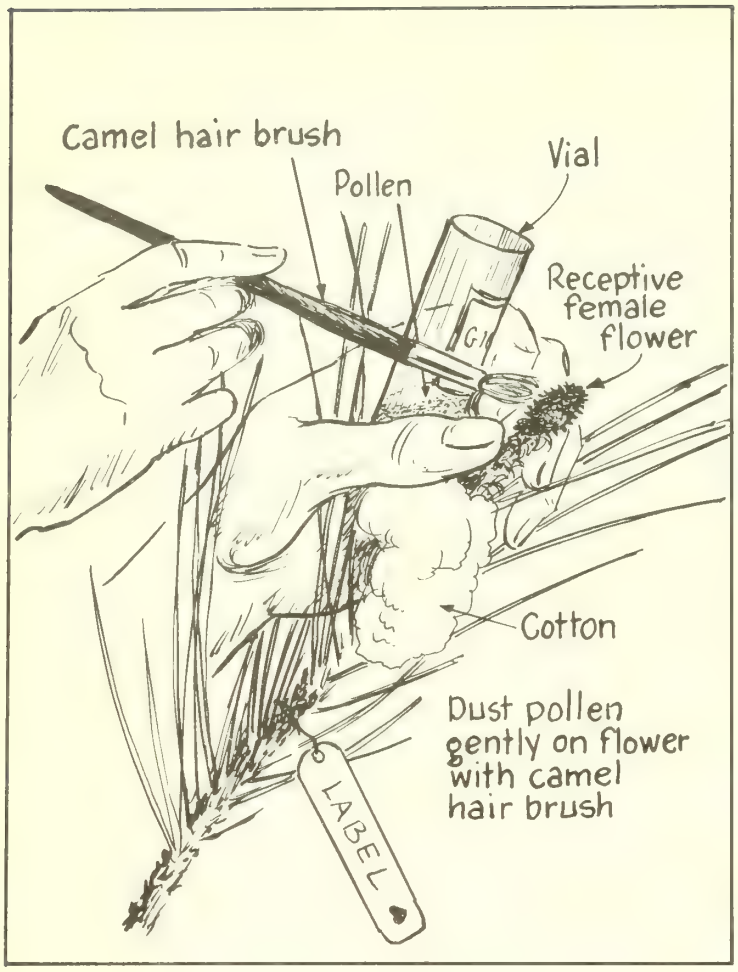


The female flowers are receptive when the scales have separated and are almost at right angles to the axis of the conelet. At this stage the ovules (swellings at the base of the scales) are visible to the unaided eye, and the scales are succulent and flesh colored.

To pollinate the flowers, the needle is pushed into the bag and pointed directly at the flowers. The best distribution of pollen is obtained if several small puffs are directed at the conelets. The scales should be covered adequately but not coated heavily with pollen. Too much pollen dries the liquid at openings to the egg cells, thus hindering pollen germination.

Permanent labels should be tied near each bag. A plastic label, code marked by a conductor's punch, is satisfactory.


LABEL POLLEN SOURCE
Plastic label
Code marks
Copper wire
Insert needle through wall of bag - blow cloud of pollen directly on to the receptive flowers. Shake bag to redistribute pollen over the flowers
Seal puncture made by needle with tape



If only a small amount of pollen is available for a particular cross, it can be brushed on the receptive flower with a camel hair brush as illustrated. To minimize the danger of contamination by stray pollen, pollination should be done during the early morning hours when the relative humidity of the air is very high and when there is no wind movement. To pollinate the flower, the bag is removed temporarily and the pollen is dusted on the conelet. The bag is replaced right after pollination. Several hundred flowers can be pollinated with 1 cc. of pollen if this method is used. This technique results in a good seed set. It is recommended for making crosses in a grafted seed orchard where flower handling does not present a problem.

To remove the bag, one can use either of the two following methods: (1) Loosen string and slip bag carefully over flowers, or (2) with a pair of scissors or a razor blade cut the bag just above tie, and slip bag over flowers. When the second method is used, the remaining collar of cotton is plainly visible for some distance and helps to relocate the labels.

The bags should be removed as soon as the scales have closed, to minimize injury to the flowers.

Remove pollination bag carefully after the scales have closed and the conelets have begun to enlarge. This happens about two weeks after pollination

PROTECTION OF CONES

Pine cones frequently are attacked by diseases, insects, and squirrels. Occasionally a destructive cone rust, Cronartium strobilinum infects very young cones, causing them to grow rapidly to an abnormal size and to assume a reddish color by mid-May. In Florida, where the disease is most prevalent, seed orchards can be protected by removing the alternate host of the disease, several species of oaks, from the vicinity.

It may be possible to control insect damage by spraying young cones with a 1-percent aqueous solution of benzene hexachloride (BHC). Such protective treatments are being tested further by the Southern Institute of Forest Genetics at Gulfport, Mississippi.

Squirrel activity in isolated trees or in seed orchards can be prevented by placing metal guards around the tree trunks. In dense forests such guards are impractical. Then it is necessary to enclose the cones in bags of wire mesh or heavy, porous cloth. If the protective bags are of tightly woven material, mold may attack the cones during periods of humid weather. So the weave must be loose enough to permit good aeration, yet tight enough to prevent loss of seeds or the entrance of cone moths.

RECORDS

Unless careful records are kept of the pollen sources which are used, one may end up with seed whose male parent is unknown or doubtful. A continuous record through the various steps will also help to determine at which stage the losses occurred. This will help a tree-breeder to improve his technique.

SAFETY

All work in the crowns of tall trees is dangerous. Take good care of ladders, ropes, and safety equipment; check position and buckles of safety belt before leaning out very far. Always push cork into needle of pollinator before placing pollinator into pocket or equipment pouch.

CONTROLLED POLLINATION RECORD

RS-8E
GENETICS
Breeding
Report form

Tree No. _____ Location: Block _____ Row _____ Column _____

Bagged (Date & No.) _____ Bags removed _____

Pollinated (Date & No.) _____ Cones collected (Date & No.) _____

Bag No.	No. of flowers	Stage	Remarks	Pollen parent	Date	No. of flowers	Remarks	Bags removed	No. of flowers	Remarks	Bag (insect)	No.	Cones collected

tation Paper No. 59 December 1955

The Grafting of Shortleaf and Other Pine Species

by

Bratislav Zak

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

A cleft graft of shortleaf pine made in 1947. Scion was taken from a typical littleleaf tree. From the start, new growth lacked any symptoms of littleleaf, and the tree, now 9 years old, continues healthy and vigorous.

THE GRAFTING OF SHORTLEAF AND OTHER PINE SPECIES

By
Bratislav Zak
Pathologist, Athens-Macon Research Center
Athens, Georgia

Current interest in grafting southern pines stems from the rather recent development of forest tree improvement and genetics programs in the South. Methods of asexual propagation, such as rooting and grafting, are important tools in carrying out these programs because they enable the investigator to take advantage of many time-saving shortcuts.

The work described here is a continuation of that reported by Jackson and Zak (3) dealing with methods of grafting shortleaf pine (Pinus echinata Mill.). Methods used in the previous studies were developed for virus transmission tests when the causal factors of the littleleaf disease were yet unknown. A large number of grafts were made, including bark patch and approach grafts on both stems and roots. Scion material was taken from healthy as well as diseased trees. Stock trees included seedlings, saplings, and adult shortleaf pines.

Upon the discovery that a root fungus was mainly responsible for littleleaf (1), efforts were directed toward the selection and breeding of disease-resistant strains of shortleaf pine (9). The experience gained from the previous studies proved valuable for this work, and various methods of grafting are now being used to propagate selected shortleaf pines. Clones of this species are being planted in a central area for later use in intensive breeding studies and for the pilot development of seed orchards.

Recent work in the South has shown that grafting other southern pines is also feasible for experimental use in genetics and for the large-scale establishment of seed orchards. Zobel (10) successfully grafted scions of Pinus taeda L. from trees of different wood densities onto the same stock seedling. Bottle and side graft methods have been successfully employed by Chase and Galle (2) in the nursery grafting of P. taeda. They also obtained good results in the greenhouse grafting of this species and of P. echinata. Mergen (4) had good success grafting P. elliottii Engelm. using succulent tissue. In another study (5), he successfully grafted scions from young succulent slash pine seedlings onto stock of corresponding age of other species and other genera, in an attempt to induce early flowering. Perry (7) grafted P. elliottii enclosing the graft in a polyethylene bag.

This study was conducted in cooperation with the School of Forestry, University of Georgia, Athens, Georgia

METHODS IN GENERAL

Grafting was done in both the nursery and the greenhouse. Potted 1- or 2-year-old seedlings were commonly employed as stock plants. Some use, however, was made of trees in situ at the nursery. Every effort was made to have these stock trees in good vigor prior to grafting. High humidity was maintained around the entire grafted tree or the scion shoot for 3 to 8 weeks after grafting. In the greenhouse this was accomplished by an automatic humidity system. For outdoor grafts at the nursery, trees were fitted with individual humidity chambers.

Scion material was, if possible, collected shortly before grafting. Otherwise, the shoots were placed in the refrigerator at 4° or 5°C. packed in moist sphagnum moss, and removed as needed. Scion material was often held for 2 or 3 weeks in this manner.

Practically all shoots from adult trees were taken from the upper one-third of the crown, which bore the most vigorous material. No attempt was made to discriminate against shoots with male and female flower buds. These, and 1-year-old cones, however, were removed during grafting in later work. A lower degree of success was observed when fruiting structures were left attached--probably because stored foods became depleted in the shoot. Perry (7), however, considers it feasible to graft flower or cone-bearing twigs. In fact, he suggests the use of this technique to provide material for controlled pollination work in the greenhouse.

For greenhouse grafting, potted stock seedlings were moved in during the first or second week of January. Grafting was begun 4 or 5 weeks later, or when top growth was resumed. Humidity was maintained at a high level from time of grafting for 6 or 8 weeks. During overcast days, especially early in spring, humidity levels up to 90 percent were possible. Later, however, during bright, sunny and warm weather, when shutters were opened, daytime humidities of 35 to 60 percent were common. At the end of this period, or when the scions showed signs of growth, the humidity was gradually reduced to normal. The process occupied 4 or 5 weeks.

Early in April, the stock trees received their first pruning, which involved the removal of one side branch. The grafted trees were then moved to the lathhouse. Gradual pruning was continued for the next 3 or 4 months, or even longer, eventually forcing the scion shoot into dominance. In most cases, the grafted trees remained under partial shade during most of the hot summer months. They were moved into the open in early fall and finally outplanted later during winter or the following spring. Since these trees had been potted and their root system confined to a rather small volume, it was found necessary to water frequently after outplanting.

Grafting outdoors in the nursery was done during early spring when bud swelling occurred. Cleft, veneer, and side grafts were commonly employed. Later, "soft tissue" grafting was successfully carried on throughout the growing season.

Some form of light, unbroken shading was always employed to prevent high temperatures within the individual humidity chambers that enclosed either the entire tree or only the scion shoot. A thin muslin cloth was found satisfactory for this purpose. From 3 to 5 weeks after grafting, humidity was gradually reduced and brought to normal in 1 or 2 weeks. The grafts were placed under lathhouse shade for the greater part of the summer and moved into the open during early fall. Outplanting was carried out in the following winter or spring.

1947-1948 GRAFTING

Several unsuccessful attempts had been made previously to graft stem shoots from littleleaf-diseased shortleaf pine onto seedlings. Such grafts were desirable as a means of testing for the presence of a possible virus in diseased trees. Methods used earlier (3), such as the bark patch and approach grafts, proved inadequate when attempts were made to explore fully the virus possibility as a cause of littleleaf.

In a 1947 experiment, scion material from both littleleaf and healthy adult trees was grafted to two rows of closely spaced 5-year-old shortleaf pine seedlings in the nursery in mid-April. A total of 114 grafts were made by the cleft, side, and needle-bundle methods. The latter method was patterned after that used successfully by Mirov (6). As each graft was made, the scion shoot was enclosed in a 1-pound, translucent, wax-impregnated paper bag. A small tear in the top provided for air exchange.

Only one graft of this entire series was successful--a cleft graft made with a short shoot from a 35-year-old littleleaf shortleaf pine, which developed an excellent union. The vigorous new growth lacked any of the foliar symptoms commonly associated with littleleaf and has so continued since.

The following year, a study[1/] was initiated to determine whether exuded resin from the cut surfaces of the scion and stock hampered union. It seemed that this resinous layer might hinder the union of the respective meristematic tissues by acting as a separator. Accordingly, treatments were devised in an attempt to remove or hold back the resin from the cut surfaces until the parts had been firmly fastened.

Apparently, little consideration has been given in past work to the effect exuded resin might have upon graft union. Mirov (6) considered the resin as beneficial. He believed that it aided in sealing the openings to the cut surfaces and thus prevented drying of the tissues. Riker, et al. (8), however, believed that this exuded resin was detrimental to successful fusion in grafts of eastern white pine. They emphasized the necessity of fastening the cut surfaces of the stock and scion securely together to prevent the formation of a "resinous barrier" between them.

1/ Zak, B. Importance of resin in the grafting of shortleaf pine. M. F. thesis, Duke University. 35 pp. 1949. (Unpublished)

The stock trees used in this study were those unsuccessfully employed during the 1947 grafting. The stems had been severed about 5 inches above the root collar to produce an abundant crop of vigorous sprouts. Some of these were over 18 inches tall and up to $\frac{1}{2}$ inch in diameter at their bases. Four of the best sprouts on each tree were selected for grafting and two additional ones left intact to serve as "feeders." The latter were gradually pruned away, beginning 3 weeks after the grafts were made.

Four treatments, including the control, were used to remove the resin or reduce its flow. All were applied to each stock tree; each stock sprout received a different treatment. These were:

1. Control.
2. Application of soft blotting paper to cut surfaces to remove exuded resin.
3. Base of scion shoot dipped in warm (50°C.) water for one minute to reduce viscosity of resin. Cuts were then made and resin removed as in 2. Warm water was not applied to stock stem.
4. Stock and scion tissues were cooled prior to cutting and fastening, in order to stiffen the resin and so prevent its exudation before the graft was fastened.

High humidity in the air surrounding each grafted scion stem was maintained by an individual humidity chamber made from a 5-gallon container open at both ends. This was placed over the stock tree and fastened to the ground. Moist peat moss was inserted and a glass pane placed over the top (fig. 1A). The outside of this chamber was coated with aluminum paint to reduce heat buildup within.

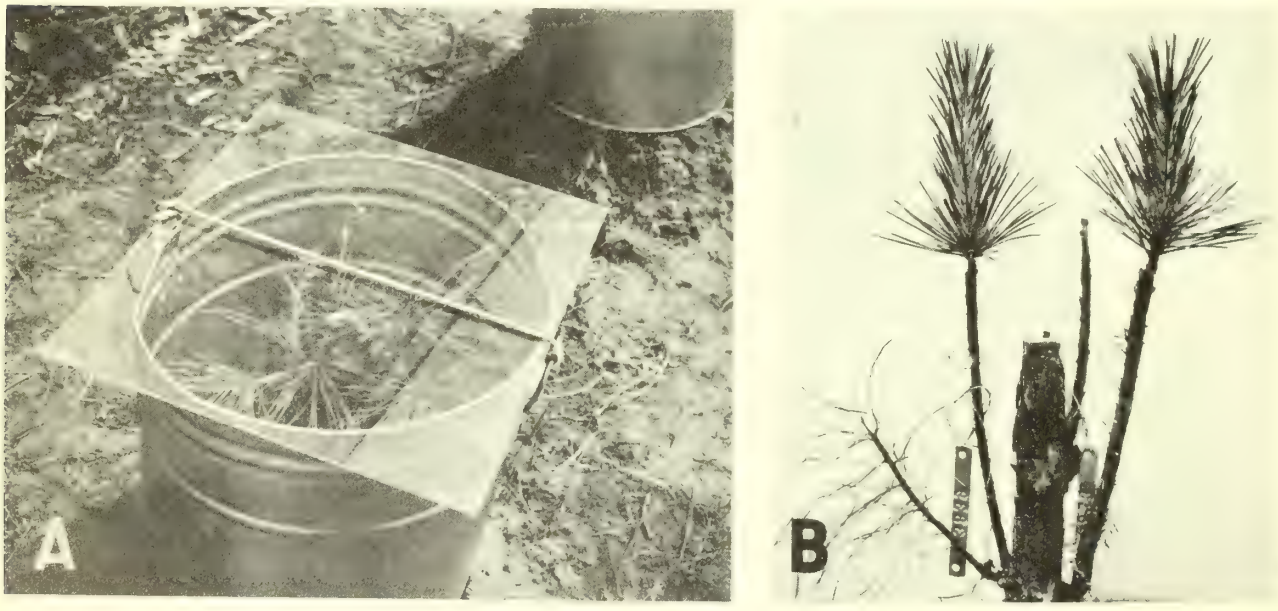


Figure 1.--Outdoor grafting of shortleaf pine. A, Portable humidity chamber installed over grafts. B, Successful grafts 2 months after grafting. Scion twigs are from littleleaf-diseased trees.

The highest success, 25 percent, was obtained in the control series (table 1). The treatments designed to remove or hold back resin failed to improve union between stock and scion. In fact, these treatments hindered union, probably by killing tissue and thus producing a "barrier" of dead cells.

Table 1.--Successful grafts by treatments and scion trees, 1948 series, shortleaf pine

Treatment	Scion trees [1] (and age in years)						
	A(42)	B(27)	C(30)	D(38)	E(34)	F(40)	All
	Percent grafts successful [2]						
1 (Control)	0	40	0	50	60	0	25
2	0	0	0	10	50	0	10
3	0	20	0	20	30	0	12
4	0	30	0	10	30	0	12
All	0	23	0	23	43	0	15

1/ A, B, and C healthy; D, E, and F littleleaf.
2/ Each value is based on 10 grafts made.

It is interesting to note the strong difference in success of grafting between individual scion trees. Inherited traits probably account for some of the differences. Surprisingly, scion shoots from diseased and apparently low-vigor trees grafted as well or even better than those from healthy and vigorous trees; possibly water loss through transpiration after removal of the humidity chambers was less from diseased than from healthy shoots. Littleleaf shoots, although apparently low in vigor, may be better adapted to the relatively xeric conditions imposed by grafting. The short length and poor retention of the needles as well as previous conditioning to a difficult water supply may contribute to this adaptation.

1953 GRAFTING

Upon completion of investigations on the cause of littleleaf, a program of selection and breeding was begun in an effort to develop littleleaf-resistant strains of shortleaf pine. For this program requiring asexual propagation of selected material, grafting was relied upon because of the lack of a reasonably successful rooting technique.

To improve grafting techniques, a greenhouse experiment was devised to test several types of grafting and a foliar treatment of the scion shoots. Bottle, veneer, and side grafts were tried. Superimposed upon the latter two methods was a wax treatment of the scion foliage. Half of the scion shoots in each group were dipped in a water mixture of Dowax. The other half served as control for this treatment. The purpose of this wax application was to reduce water loss from the scion tissue until sufficient union had developed.

Although the greenhouse was humidified, rather low humidities were experienced during warm sunny days as the season advanced.

Scion material from 8 selected shortleaf pines ranging in age from 33 to 81 years was grafted onto 2-year-old potted shortleaf pine stock seedlings during mid-February. When new growth began, scion material was collected from each tree, all located 150 miles distant, packed in moist sphagnum moss and stored in the refrigerator until needed.

The veneer and side grafts of the non-wax-dipped series were most successful (table 2). Seventy-six percent of the veneer grafts and 75 percent of the side grafts made good union. In general, dipping the scion shoots in Dowax adversely affected union in both methods. This treatment caused injury to the foliage; after 2 weeks, needles turned brown and water-soaked in appearance about halfway down from the tips. The wax emulsion used was apparently an older formulation containing toxic ammonium linoleate as emulsifying agent. The present Dowax is said to be free of agents injurious to plant tissue.

Table 2.--Successful grafts by treatments and scion trees, 1953 series, shortleaf pine

Scion tree		Type of graft					
No.	Age [1]	Bottle ND [2]	Veneer ND	Side ND	Veneer D	Side D	All
	Years	Percent grafts successful [3]					
Z-1	35	50	90	100	70	80	78
Z-3	42	30	30	30	20	50	32
Z-7	33	0	90	70	60	40	52
Z-13	78	80	80	60	50	50	64
Z-14	81	0	100	90	40	40	54
Z-15	81	0	100	100	70	90	72
Z-16	50	0	60	70	60	20	42
Z-17	69	0	60	80	80	60	56
All		20	76	75	56	54	56

1/ Core count plus 3 years.
2/ ND means not dipped in Dowax; D means dipped.
3/ Each value is based upon 10 grafts made.

The bottle graft gave the poorest results, with only 20 percent of unions successful. This relative failure may be attributed to the post-grafting treatment. Six weeks after the grafts were made, the bottles supplying water to the bases of the scion shoots were removed. Scion stems were then severed

just below the union, since little if any water was being removed by the scion stems and bacterial contamination was feared. About one week later, many of the scion shoots commenced to brown and die. Greenhouse humidity was being gradually reduced at this time but was still rather high except on bright warm days.

1954 GRAFTING

Another group of shortleaf pines, selected for apparent resistance to littleleaf, was propagated by grafting in the greenhouse during 1954. These trees were all located in Union County, South Carolina. The techniques were similar to those employed in the 1953 work. However, only the side and veneer grafts were tried. Two-year-old potted seedlings of both shortleaf and loblolly pine served as stock trees.

Only 27 percent of the grafts were successful (table 3). Shortleaf grafted on shortleaf pine stock gave 37 percent, and shortleaf on loblolly pine stock 17 percent successful unions. Again a wide variation in grafting ability among scion trees is apparent.

Table 3.--Successful grafts of shortleaf pine scions on shortleaf and loblolly pine stocks, 1954 series

Scion tree		Stock species grafted		
No.	Age [1]	Shortleaf stock	Loblolly stock	All
	Years	Percent grafts successful [2]		
Y-1	70	27	58	43
Y-2	45	91	0	46
Y-3	45	18	7	13
Y-4	46	49	0	25
Y-5	45	94	0	47
Y-6	89	38	38	38
Y-7	43	0	7	4
Y-8	46	29	36	33
Y-9	52	20	40	30
Y-10	42	9	0	5
Y-11	43	27	0	14
All		37	17	27

1/ Core count plus 3 years.
2/ Each value is based on 45 grafts made.

Experimental work was also done with "soft tissue" or succulent grafts using techniques similar to those employed by Mergen (4) in grafting slash pine. By this method a small immature shoot is grafted into the growing tip of the stock seedling, generally by the cleft type of joining. Unlike most other forms of grafting, the shock upon the stock plant is greatly lessened since only a small section of stem is removed. Little if any pruning is required later. Union between the two parts is very rapid. Apparently, a high proportion of tissue other than the cambium may become meristematic in such young stems. The almost intact crown of the stock seedling promotes a high rate of food production and rapid tissue formation.

The soft tissue method is simple. An immature scion stem with needles only slightly developed (fig. 2A) is cleft-grafted into the growing terminal of the stock seedling. The scion shoot is cut to a length of about 1 or 2 inches and the basal end shaped into a wedge. A corresponding length of growing tip of the stock tree is removed. A short vertical cut is made into this stub and the scion stem inserted. Little care is necessary in aligning the cambial zones. The graft is then firmly wrapped with soft cotton thread (fig. 2B). Instead of being tied, the thread-wrapping is smeared on one side with a small bit of softened grafting wax to prevent unraveling. Finally, the top portion of the stock tree, including the newly-grafted scion, is enclosed in a 2-pound cellophane bag (fig. 2C). A few holes, totaling about one-half inch in area, are cut in the top for aeration. Throughout this process, care is exercised to prevent wilting of the scion shoot. The grafted seedling is then placed under a light unbroken shade. Three weeks later, the cellophane bag is partially opened to lower the humidity within. The following week, it is completely removed and the tree placed in the lathhouse. A month or two later, the grafted seedling is moved into full sunlight.

Table 4 presents the results of inter- and intra-specific grafting by this method. Scion material was taken mainly from seedlings but equally good results can be expected from older material. In most cases the union between stock and scion (figs. 2E and 2F) was excellent. Equally good results were obtained in early spring, in midsummer, and in late summer. Some of the grafting was done with no apparent adverse effects when air temperatures ranged near 35°C.

An important factor limiting this method of grafting pine is the availability of suitable scion material. On large and vigorous trees the young shoots may be too large and thick for use with this technique. Possibly this difficulty may be overcome by pruning the buds from the ends of branches to stimulate the development of several small shoots from needle bundles. It is believed this treatment may be used successfully with shortleaf and loblolly pine if pruning is done about 3 to 4 weeks before the material is needed.

Soft tissue grafting will be of considerable use to foresters in expanding the existing clones already in seed orchards. One- or two-year-old grafted trees will have sufficient crown to supply additional scion tissue. Very light pruning or even tip moth damage of these trees will encourage the development of many small shoots. Each tree should supply 10 or 15 scion stems without harm.

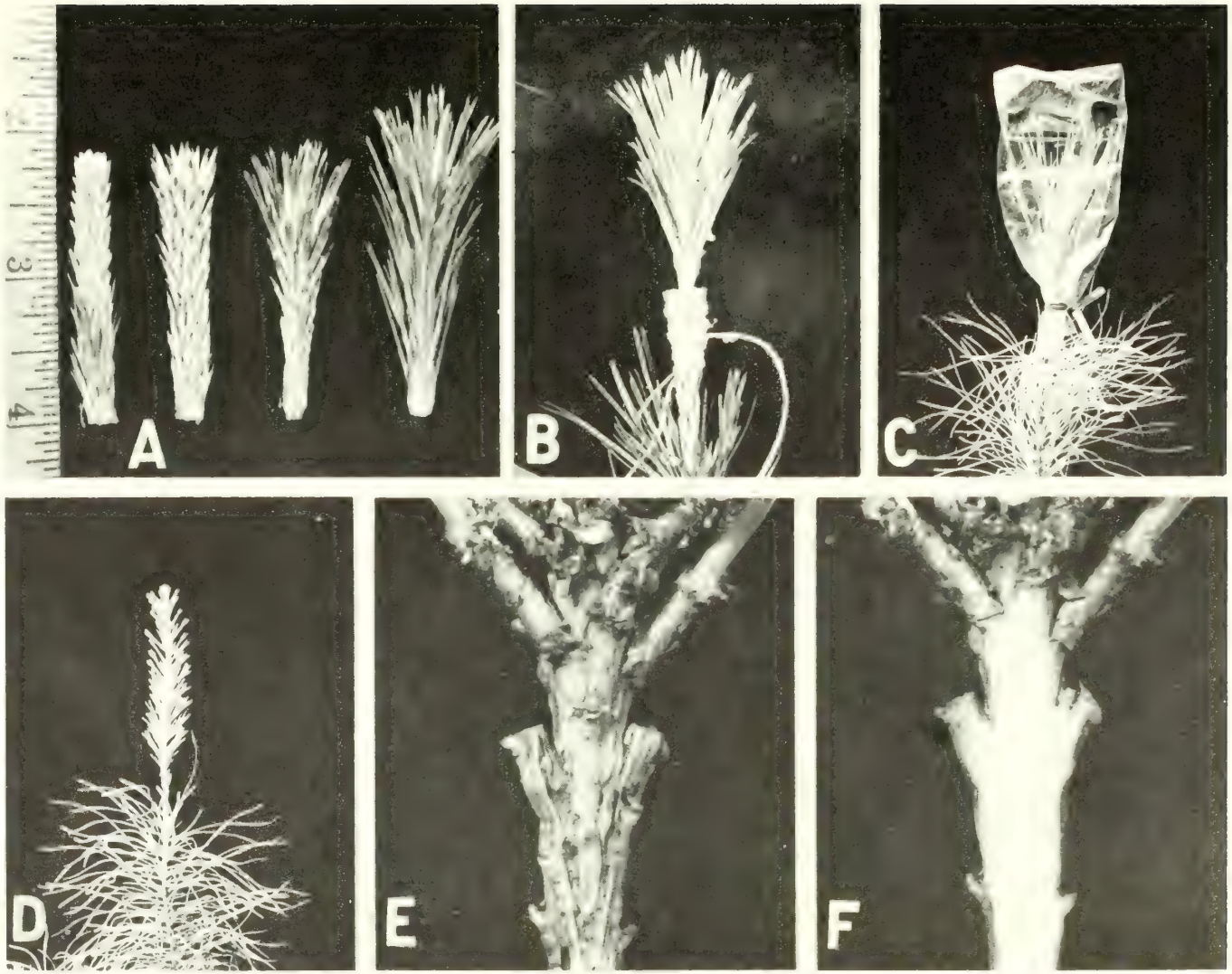


Figure 2.--Soft tissue grafting of pine. A, Scion shoots suitable for use with this method. B, Completed graft. C, Graft enclosed in cellophane bag to maintain high relative humidity in air surrounding scion shoot. D, Graft of shortleaf on Virginia pine stock after 2 months. E, Close-up view of graft union. F, Graft union of E cut open to show excellent fusion of scion and stock.

Table 4.--Soft tissue grafting results, 1954 series

Scion tree		Stock tree		Grafts	
Species	Age	Species	Age	Made	Successful
	Years		Years	Number	Number
Shortleaf	3-46	Shortleaf	2	25	18
Loblolly	2	Loblolly	2	5	4
Loblolly	2	Shortleaf	2	4	2
Shortleaf	2	Loblolly	2	8	5
Slash	2	Loblolly	2	4	2
Slash	2	Shortleaf	2	3	2
Loblolly	2	Virginia	2	3	1
Shortleaf	2	Virginia	2	3	3
Eastern white	30	Virginia	2	5	2

GENERAL DISCUSSION

Success or failure of plant grafting is largely a matter of water relationships in the scion stem and later in the scion-stock combination. After the scion shoot has been severed from the parent plant and lacks a significant source of water, loss of water by transpiration may continue at a high rate and lead to dehydration of the tissue. The problem then becomes one of water conservation until adequate connective xylem is formed between stock and scion. Once a good union had developed, sufficient water can pass from stock to scion to replace that lost by transpiration.

Transpiration of water from the scion stem is dependent on environmental conditions and on the character of the shoot itself. Full sunlight, high air temperature, and low relative humidity in the air surrounding the scion all contribute toward a high rate of transpiration. Therefore, when grafting, it is desirable to provide some form of shading and to maintain high relative humidity of the air. Shading is used only to reduce heat build-up within the greenhouse or humidity chamber. Adequate light is desirable for synthesis of food to promote rapid tissue formation.

The type and size of scion shoots must also be considered. Succulent material, as used in soft tissue grafting, is far more sensitive to conditions of high transpiration than is mature and hardened tissue. The writer found that tender shoots open-grafted in the greenhouse readily wilted without recovery after 1 or 2 days. Even under humidification, levels as low as 35

percent relative humidity were encountered on bright warm days. No early wilting occurred when the shoot was enclosed in a cellophane bag (fig. 2C) together with some of the stock foliage. Humidity within was almost continuously near saturation.

When mature stems are being grafted, the portion above the union should be relatively short in length. Less surface is thus exposed to transpiration. Often, half the length of the remaining needles is sheared off to further reduce water loss from the scion stem. A suitable nontoxic wax emulsion applied over the foliage might be useful in lowering water loss.

The extent and rapidity of union between stock and scion are also important factors in successful grafting. The greater the area in contact between the two parts, the better the chance of success. It is important, therefore, to match the diameters of the two stems so that cambial zones on both sides can be aligned. Stems of unequal size may be used, however, by carefully regulating the depth of cut so that width across the cut surface of each is approximately the same. Accurate alignment of the stems is necessary for success. Rapid knitting of the union is promoted by favorable growing conditions and by the use of vigorous stock.

Finally, careful consideration should be given to the manner of pruning the stock tree after grafting, in order to force the scion shoot into dominance. Little if any pruning is necessary with the soft tissue grafts; but when mature stems are grafted by the bottle, side, or veneer methods, pruning of the stock tree is desirable. Eventually all stock tissue above the union is removed, leaving only the scion to grow.

Too early and too rapid pruning often result in graft failures. Quick removal of the stock crown after grafting causes too great a reduction in the stem diameter growth, and consequently delays or even prevents the development of a sound union. Pruning, therefore, should be gradual and should extend throughout most of the growing season. Actually, each tree should be treated individually according to its size and according to the rate of development of the scion shoot. The first pruning should always be very light. Removal of a small side branch may be sufficient. Then as the volume of scion foliage increases, more and more of the stock crown can be removed until only that of the scion remains.

SUMMARY

The grafting of shortleaf and other pine species in connection with investigations of the littleleaf disease is described and the factors affecting successful grafting are discussed.

The work reported is a continuation of that described by Jackson and Zak (3). Studies from 1947 to 1954 are included. Grafting techniques were first employed to test a virus hypothesis for littleleaf and later as tools in the selection and breeding of littleleaf-resistant pine.

Various grafting methods such as the cleft, bottle, side, veneer, and "soft tissue" were used, both in a humidified greenhouse and outdoors in the nursery. Scion material from trees ranging in age from 2 to 89 years was successfully grafted.

In a 1947 experiment, only 1 graft of 114 was successful. The next year, a study was carried out to test the effect of exuded resin upon union between stock and scion. Treatments used to remove or retard resin flow proved injurious to exposed tissues and caused a reduction in the number of successful unions. Successes up to 60 percent of the grafts were obtained for individual scion trees and treatments.

Bottle, side, and veneer grafts were tested in another study using shortleaf pine. A Dowax dip-treatment of the scion shoots was superimposed upon the side and veneer methods. The undipped series of the side and veneer grafts gave about 75 percent success and the wax-dipped series only 55 percent. The lower success of the latter is ascribed to toxicity of the emulsifying agent contained in an older formulation of the wax used. Bottle grafts were only 20 percent successful.

Both shortleaf and loblolly pine stock seedlings were used in a 1954 trial. Scion material came from selected shortleaf pines. Shortleaf scions on shortleaf pine stock gave 37 percent and shortleaf on loblolly pine gave 17 percent success. As in previous work, individual scion trees varied greatly in their ability to form successful unions.

The soft tissue method of grafting is described and the results of various inter- and intra-specific grafting are given. The method shows great promise for use in tree improvement and genetics investigations. It may prove especially valuable for expanding existing clones in seed orchards.

The principal factors affecting successful union in pine grafting are discussed. Water relations of the severed scion stem and later of the stock-scion combination are deemed of prime importance.

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An Allowance for Bark Increment in Computing Tree Diameter Growth for Southeastern Species

by

James F. McCormack

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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AN ALLOWANCE FOR BARK INCREMENT IN COMPUTING TREE DIAMETER GROWTH FOR SOUTHEASTERN SPECIES

By
James F. McCormack

INTRODUCTION

Foresters concerned with estimates of timber volume growth on any area or tract must first of all determine the rate of increase in tree size. The most important measurement, and often the only one made, is of the change in tree diameter at breast height over a specified period of years. Increment cores taken at this point 4.5 feet above ground are commonly used to measure the combined radial growth of a number of annual rings. This method provides data on the rate of wood growth, but it is impractical for measuring changes in bark, which slowly increases in thickness over the years.

Tables giving the volume of wood in a tree are customarily based on measurement of tree diameter outside bark. In growth computations, therefore, the usual problem is to find the outside-bark diameter, and thus the volume, of sample trees at the beginning of a growth period. Where no allowance is made for bark growth and the past tree diameter is obtained by subtraction of wood growth alone, an underestimate of the actual increase in diameter ranging up to 17 percent may be introduced into the computations.

The purpose of this paper is to describe a method of taking the change in bark thickness into account, and also to present a set of growth factors suitable for use with southeastern species. The method used here is an adaptation of the procedure published by Meyer [1/] in 1942 for the determination of diameter increment. The growth factors are constants developed from field data which serve a dual purpose. They provide the needed allowance for bark growth by individual species, and they also convert radial growth, as measured on the increment core, directly to diameter growth including wood and bark.

1/ Meyer, H. Arthur. Methods of forest growth determination. Bulletin 435, Pennsylvania State College, School of Agriculture, 93 pp., illus. December 1942.

THE SAMPLE DATA

Bark thickness has been measured on thousands of sample trees in the Southeast by the Forest Survey for use in growth estimates. Sample trees were selected on ground plots under a strict area basis according to tree size so they would be representative of average timber stands. Field crews using the Swedish bark gauge measured the radial thickness of bark to the nearest 5 one-hundredths of an inch. This measurement was made at breast height on trees of normal form. It was always made on the plot-center side of the sample tree except on pronounced slopes, where the measurement was made on the uphill side. On swell-butted species such as cypress and tupelo gum growing in swampy areas, the measurements of both tree diameter and bark thickness were made at a point called "bottleneck," which is 18 inches above the top of the pronounced swell. Single bark thickness was doubled to obtain total thickness of bark in tenths of an inch. This value was subtracted from the outside-bark diameter of the tree, as measured with a diameter tape, to obtain inside-bark diameter.

Most of the bark data used in developing the growth factors were collected on sample plots in Virginia, South Carolina, Georgia, and Florida. Some additional data were obtained from a number of other studies in southeastern states where bark measurements had been made. The data, identified by source, species, and tree size, were punched in IBM cards for summary and analysis.

RATIO OF OUTSIDE TO INSIDE BARK DIAMETER

The relationship of diameter outside bark (d.o.b.) to diameter inside bark (d.i.b.) was used to derive the growth factors. The data were separated by species, and the measurements in inches and tenths were summed up by 2-inch diameter classes. Average values for diameter outside and inside bark were then computed for each class and plotted on coordinate paper as shown in figure 1. This relationship is linear and may be adequately represented by a straight line drawn through the plotted points. Such a line was fitted to the data for each species by the method of least squares. The degree of correlation between the two diameter measurements is obviously very high.

The regression equation $Y = a + bX$ was used in fitting the lines to d.o.b. plotted over d.i.b. For loblolly pine, the expression turned out to be d.o.b. = .703 + (1.095)d.i.b. The regression coefficient 1.095 gives the slope or rate at which the line is rising. In other words, it is a ratio which shows the change in outside-bark diameter per unit of change in inside-bark diameter. Thus, for loblolly, diameter outside bark increases 1.095 inches for each increase of 1 inch in diameter inside bark.

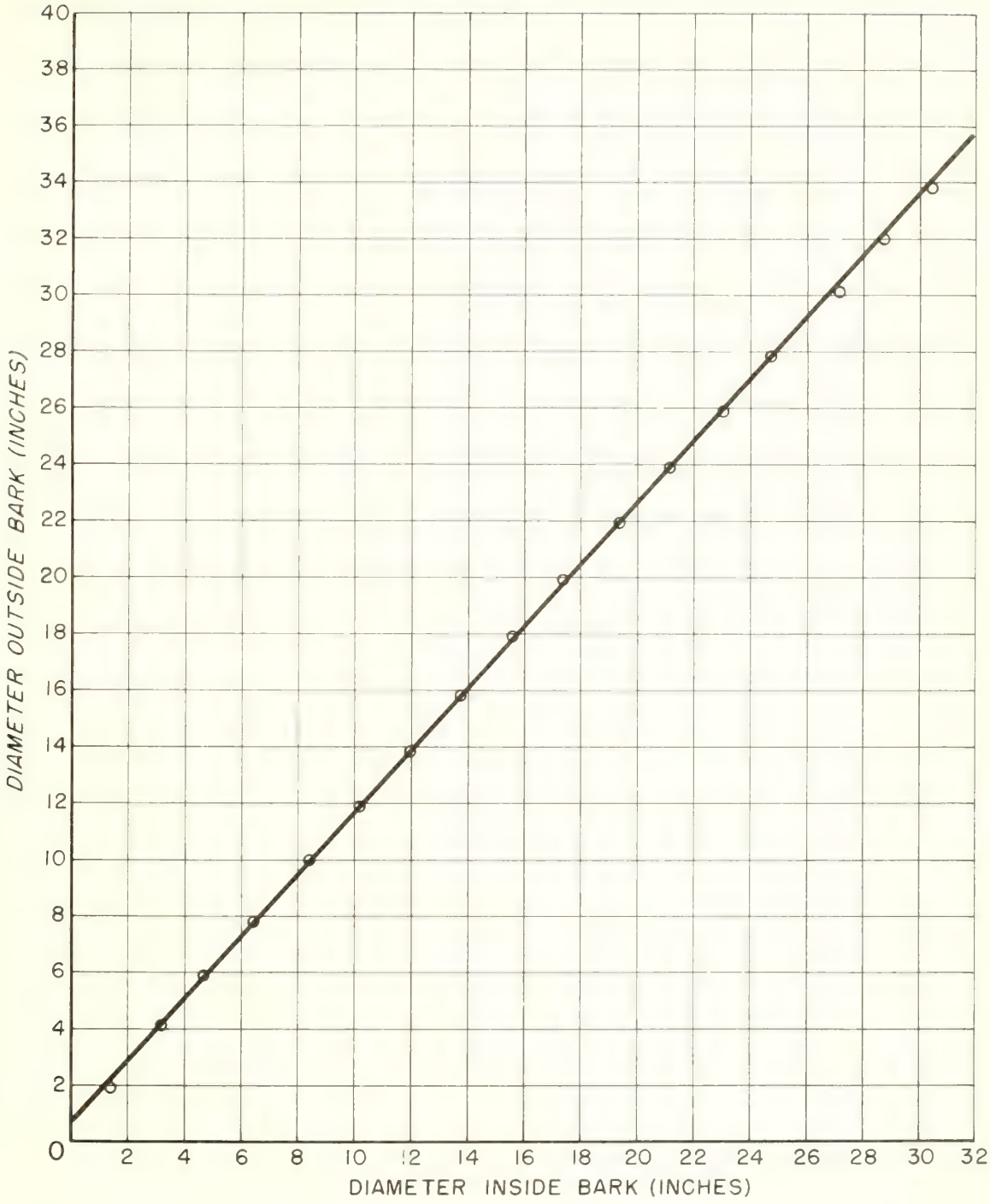

Figure 1.--Relation of diameter outside bark to diameter inside bark for loblolly pine.

COMPUTATIONS OF GROWTH FACTORS

As Meyer points out, this relationship is useful for estimating tree diameter growth which, of course, is made up of increases in the thickness of both wood and bark. The d.o.b.-d.i.b. ratio may be used as a constant in the computations to add the proper amount of bark increment to the growth of wood. Since we are starting with the radial growth of wood alone, as measured on the increment core, the formula for tree diameter growth outside bark can be written as follows:

$$Dg = 2(K \cdot Rg)$$

Where: Dg is the increase in outside bark diameter

Rg is the measured radial growth of wood

K is the regression coefficient or constant

Diameter growth of trees can be visualized in cross section as a radial increase in both wood and bark on each side of the tree bole. It is, therefore, necessary to double the d.o.b.-d.i.b. ratio in the formula, as well as the radial growth of wood, to make allowance for bark growth which also takes place on both sides of the tree.

Then, for loblolly pine, the growth factor is:

$$Dg = 2(1.095Rg)$$

$$= 2.190Rg$$

Factors for other species shown in the following table were computed in a similar manner. In this form, they minimize the amount of hand or machine arithmetic needed to obtain tree diameter at the start of a growth period. For further simplicity in use, they have been rounded to two decimal places at the expense of a very small loss of accuracy.

APPLICATION OF THE FACTORS

Radial growth of wood is simply multiplied by the proper species factor to obtain total diameter growth of the tree for the period involved. For example, if we assume a 10-year radial wood growth measurement of 1.1 inches for a loblolly pine which is now 13.2 inches in diameter, then the total diameter growth including bark is:

$$(1.1)(2.19) = 2.4 \text{ inches}$$

The outside bark diameter of the tree at the beginning of the period, obtained by subtraction, would be:

$$13.2 - 2.4 = 10.8 \text{ inches.}$$

Growth factors for southeastern species

Species	Growth factor	Number of trees sampled
Yellow pines:		
Loblolly pine	2.19	2,654
Longleaf pine	2.12	1,581
Pitch pine	2.15	93
Pond pine	2.17	258
Sand pine	2.12	57
Shortleaf pine	2.17	1,681
Slash pine	2.14	1,205
Spruce pine	2.11	54
Table Mt. pine	2.12	16
Virginia pine	2.20	742
Other softwoods:		
Cedar, Atlantic white	2.20	15
Cedar, eastern red	2.07	44
Cypress, bald	2.05	167
Cypress, pond	2.15	569
Hemlock	2.18	113
White pine	2.23	117
Hardwoods:		
Ash	2.10	249
Basswood	2.11	66
Beech	2.04	90
Birch, yellow	2.07	29
Birch, black	2.17	16
Birch, river	2.19	29
Buckeye	2.09	21
Butternut	2.14	11
Cottonwood	2.21	23
Cucumber	2.20	29
Hardwoods (continued)		
Dogwood	2.18	22
Elm	2.10	139
Gum, black	2.15	1,214
Gum, sweet	2.07	950
Gum, tupelo	2.12	105
Hackberry	2.08	33
Hickory	2.11	461
Holly	2.10	29
Locust, black	2.40	19
Maple, hard	2.07	53
Maple, soft	2.10	485
Oak, black	2.13	221
Oak, chestnut	2.18	160
Oak, laurel	2.11	317
Oak, live	2.13	59
Oak, northern red	2.15	169
Oak, overcup	2.10	41
Oak, post	2.19	120
Oak, scarlet	2.11	572
Oak, southern red	2.14	152
Oak, swamp chestnut	2.08	66
Oak, swamp red	2.14	36
Oak, water	2.10	305
Oak, white	2.16	873
Oak, willow	2.09	132
Poplar, yellow	2.18	599
Sycamore	2.09	46
Sweetbay	2.16	257
Walnut, black	2.27	27

Without the allowance for increase in bark thickness, the radial growth of wood only would be doubled, resulting in an estimated 2.2 inches of diameter growth and a past diameter of 11.0 inches for the tree. This procedure would be in error since it underestimates the actual tree diameter growth by 8 percent and, in this example, would place the tree in the wrong diameter class at the start of the growth period. An error of this type is non-compensating and will carry forward into computation of volume growth with varying effect depending on the size of the sample tree.

Although a number of factors in the table are the same, or very similar, they are shown separately for ease in use, and also because volume tables for individual species may be significantly different. In case it is desirable to use a single factor for a group of species, such as the yellow pine, a weighted factor can easily be developed by using the number of sample trees of each species in the stand as weights for the individual factors.

The sampling error of individual factors varies from about ±1 percent for a heavily sampled species such as loblolly pine to ±11 percent for black locust, which was sampled very lightly. Regression curves were also tested for geographical differences, but no significant variations were found.

These factors are now being used by the Forest Survey in growth computations, which are handled on punch card equipment. The bark thickness data obtained so far are adequate, at least for the more important species, and collection of bark measurements in the field has been discontinued. Since the factors are based on representative stand data over broad areas, they should be sufficiently accurate for general use in the Southeast.

Agriculture-Asheville

Station Paper No. 61 December 1955

Loblolly Pine Seed Tree Mortality

by

Kenneth B. Trousdell

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

LOBLOLLY PINE SEED TREE MORTALITY

By
Kenneth B. Trousdell

To keep the land in continuous production, the seed-tree method of cutting is commonly used in loblolly pine stands of the coastal plain of North Carolina and Virginia. By this method selected trees are left standing for varying lengths of time after logging to furnish seed for the next generation of timber. The main body of this paper is concerned with the rate and extent of loss of these valuable seed trees through mortality from various causes as observed in a large-scale test of different management systems on the Bigwoods Experimental Forest[1/] from June 1948 to October 1954. The damage done later by a recent hurricane is discussed separately to show the effects of this storm on seed-tree stands.

This study shows that more seed trees die during the first few years following logging or major cultural measures than in later years. Some of the early mortality is associated with tree injury or change in environment that occurs during logging or cultural treatment. This mortality can be decreased by more careful logging and less severe cultural treatments. After two or three years the principle causes of tree mortality are lightning and wind. Mortality from the latter causes will continue as long as the seed trees stand above the young forest. Leaving 2 trees per acre to insure seed in case of a wildfire is not enough, and thus the practice is not recommended.

THE STUDY AREA

The Bigwoods Experimental Forest is a 1365-acre tract which was well stocked with mature loblolly pine when it was established in 1945. The forest was divided into 37 compartments, each with an area of about 35 acres, in a comprehensive test of different methods of even-aged and many-aged management. On 22 areas seedling stands were established by natural seeding following seed-tree or alternate-strip cuttings. Eight large, well-spaced, seed trees were left per acre on 14 of these compartments. The 8 additional areas were cut by the alternate-strip method. Strips 1 chain wide were left as a seed source and intervening strips 3 chains wide were clearcut. After the resultant seedling stands from either of these cutting methods were judged to be satisfactory, a second cut was made removing all merchantable pines except 2 trees per acre which were termed "insurance trees."[2/]

1/ Maintained by the Southeastern Forest Experiment Station in cooperation with Camp Manufacturing Company, Inc., Franklin, Virginia.

2/ In the remainder of the text, the term seed trees refers to trees left in stands of 8 per acre, and the term insurance trees refers to trees left in stands of 2 per acre after removal of the seed source.

During the period of June 1948 to October 1954 a record was kept of the pine seed trees left standing on each area until the trees were harvested. Trees that died were recorded by size and suspected cause of death. The final inventory of tree mortality was made on all areas in October 1954. A total of 3,802 seed trees on 494 acres were left for an average period of 3.3 years, and 1,291 insurance trees on 674 acres were left for an average period of 2.1 years. In the seed-tree stands the average tree was 19.7 inches d.b.h. with an estimated volume of 520 board-feet per tree. The insurance trees were smaller, averaging 17.2 inches d.b.h., with an estimated volume of 360 board-feet per tree.

TREE INJURY AND SUSPECTED CAUSE OF MORTALITY

In spite of careful supervision when the stand was cut, 8 percent of our seed trees were severely damaged in the felling operation or during tractor logging. The majority of the damage (6 percent) occurred at the base of the trees and was caused by the skidding operation. A tree that was barked a minimum of 10 inches or 1/3 of the circumference was classed as severely damaged. Severe felling damage (2 percent) included all trees barked along the main bole or having a major limb broken in the crown. Logging damage has been the apparent cause of death of 5 percent of the injured trees.

In one winter logging operation, the heavy soil was churned into mud at a loading point and 6 seed trees located in the area died. Severe mortality has been observed on other cutover tracts following tractor logging on poorly drained plastic soils when the water table was near the surface. This type of damage has been reported by McCulley. 3/

A fire treatment designed to improve the seedbed for pine regeneration was used on half the areas. In this treatment, the cutover area was burned after logging and prior to seedfall. The post-logging fires usually generated hot columns of air from slash concentrations and resulted in occasional crown scorch. Most of the severely scorched trees died. To our knowledge no large pine was killed primarily by heat at the base of the tree.

In assigning a primary cause for tree mortality, the recorder used his best judgment. Dead trees that had visible signs of injury by fire, logging, lightning, or wind were listed under the appropriate cause (table 1).

This simple enumeration of trees that died emphasizes the importance of lightning and wind (excluding the 1954 hurricane) in comparison to all other mortality both during the period immediately following logging and in later years after the effects of tree injury and drastic change in environment have diminished. If the 11 dead trees with no record of cause are eliminated from the tabulation, trees that died from causes other than lightning and wind are 47 percent of the total for seed trees and 7 percent of the total for insurance

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3/ McCulley, Robert D. Wet-weather logging may damage seed trees. Virginia Forests 5(5): 6. 1950.

trees. It is apparent that losses from lightning and wind continue over long periods of time and account for over 90 percent of all losses after the seedling stands are established.

Table 1.--Suspected cause of mortality for seed trees and insurance trees

Suspected cause of mortality	Seed trees (8 per acre)	Insurance trees (2 per acre)
	Number	Number
Fire	1/ 15	--
Logging and insects	25	2
No apparent cause	17	1
No record of cause	7	4
Lightning	34	29
Wind (excluding 1954 hurricane)	29	14
Total	127	50

1/ One half of the seed-tree areas were burned.

RATE OF MORTALITY

The period of record varied from 1.3 to 5.8 years for stands of 8 seed trees and from 0.4 to 4.7 years for insurance trees. In all there were 14 seed-tree areas and 18 insurance-tree areas under observation.

In order to get all data on a comparable basis, particularly in view of the unequal periods of time involved, the period that a stand stood undisturbed in tenths of years and the acreage were used to compute units of 100 acres for 1 year. This area-time unit is used to compare the relative rates of mortality for each compartment (table 2). As the average seed-tree and insurance-tree areas are 35 and 37 acres respectively, the period of observation can be estimated for each area in the table. For example the first unit of observation is 1.91 hundred-acre years, or approximately 35 acres for 5.5 years.

The use of a fire treatment at the time of regeneration was a major comparison in the regeneration experiment. From our experience the post-logging fire increases the number of seed trees that die. More than 10 trees died per 100 acres per year on burned compartments, while the rate was less than 5 on unburned areas. It seems improbable that lightning and wind mortality are related to the fire treatments. When these causes are eliminated, 4.9 trees died per 100 acres per year on burned, and 2.7 trees on unburned areas. Mortality from all causes other than lightning and wind was increased 2.2 trees per 100-acre-year unit, or 81 percent by the burning treatment.

Table 2.--Basic record on 32 areas showing unit of observation, number of trees dying, and rate of mortality per 100 acres per year for seed trees and insurance trees

Stand description	Unit of observation, 100 acres	Trees dying	Mortality per 100 acres per year	
			All causes	Excluding wind and lightning
	Years	Number	Number of trees	Number of trees
8 seed trees per acre (not burned)	1.91	8	4.2	2.6
	1.61	4	2.5	1.2
	1.03	7	1/ 6.8	3.9
	.83	6	7.2	2.4
	.78	2	2.6	2.6
	.72	5	6.9	6.9
	.59	3	1/ 5.1	0.0
Subtotal or average	7.47	35	1/ 4.7	2.7
8 seed trees per acre (burned)	2.17	21	9.7	6.9
	2.06	15	7.3	5.3
	1.61	15	1/ 9.3	0.0
	1.17	18	1/ 15.4	1.7
	.89	10	11.2	9.0
	.58	11	1/ 19.0	10.3
	.42	2	4.8	4.8
Subtotal or average	8.90	92	1/ 10.3	4.9
Total all seed trees	16.37	127	1/ 7.8	3.9
2 insurance trees per acre selected from strips	2.12	2	0.9	0.0
	2.11	7	3.3	0.5
	1.46	1	0.7	0.7
	1.35	5	3.7	1.5
	1.25	3	2.4	0.0
	1.02	5	4.9	0.0
	.27	0	0.0	0.0
	.19	1	5.3	5.3
Subtotal or average	9.77	24	2.5	0.5
2 insurance trees per acre selected from seed trees	.93	8	1/ 8.6	1.1
	.88	6	1/ 6.8	1.1
	.63	3	1/ 4.8	0.0
	.60	2	1/ 3.3	0.0
	.55	2	3.6	0.0
	.23	2	1/ 8.7	0.0
	.23	2	1/ 8.7	0.0
	.23	0	0.0	0.0
	.19	1	5.3	0.0
	.14	0	0.0	0.0
Subtotal or average	4.61	26	1/ 5.6	0.4
Total all insurance trees	14.38	50	1/ 3.5	0.5

1/ Includes wind mortality

The insurance trees were expected to stand for long periods, perhaps until the end of the rotation. Thus, thrift and freedom from injury were important considerations when they were selected. Within this group of trees, lightning and wind accounted for 3 of the 3.5 trees that died per reporting unit. This rate of mortality will continue and presumably will not diminish until the trees are all gone.

The occasional wind storms that have destroyed seed trees generally occurred along the squall fronts of violent summer storms. The appearance of broken trees indicates that twisting of the tree was the cause of failure. The damage occurred in small streaks over the area, with most trees breaking or being upturned by winds from the west and southwest. Because of the nature of the storms, wind damage has been erratic, occurring on only 5 of the 14 seed-tree areas and 6 of the 18 insurance-tree areas. Where wind damage is a factor, the rate per reporting unit is high because normally 2 or more trees were destroyed by a storm (fig. 1).

In the tabulation of insurance tree stands (table 2), the first eight entries are from compartments in which the trees were selected from uncut strips. The strips contained trees of all crown classes, and insurance trees were selected for thrift and small volume. There was no wind damage recorded in these eight stands for relatively long periods. It is probable that the violent summer storms would be less damaging to stands of younger and smaller seed trees.

LIGHTNING AND OTHER MORTALITY

Two distinct forest conditions were represented on the Experimental Forest before cutting. One was an overmature old-field pine stand growing in well-drained terrace soil, and the other was forest-grown pine with two age classes: 60 to 80 years, and over 100 years. Fire treatment was used on one-half of the compartments in both the forest grown and old-field stands, so that an over-all comparison of mortality between these two forest conditions is not influenced by the burning treatment.

When the data are arranged by stand origin and number of trees (table 3) the relative importance of lightning, wind, and all other mortality is shown for the period of regeneration with seed trees and during later years with insurance trees.

On areas cut to seed trees the loss was less than 1 percent of all trees per year for the regeneration period. If 800 seed trees were left on 100 acres for 4 years and all mortality could be concentrated in one area of 4 acres, then 31 trees would be dead and only 1 would remain. Of the 4 acres with dead trees, the mortality by area might be distributed as follows: 2 acres to injury and drastic change in environment, 1 acre to lightning, and 1 acre to wind. After stands were reduced to insurance trees, the percent of annual rate of mortality increased to 1.75 percent. With 200 trees left on 100 acres for 4 years, 14 trees may be expected to die or the equivalent of 7 acres of insurance trees. Lightning now has accounted for mortality on 4 acres, wind on 2 acres, and all other causes on 1 acre.

Figure 1.--A seed tree twisted off by summer storm.

Table 3.--Mortality of pine leave trees per 100 acres per year during regeneration (seed trees) and young stand development (insurance trees)

Stand description	Lightning	Wind	All other causes	All causes
	Number	Number	Number	Number
8 seed trees per acre				
Old field	2.1	2.5	2.8	7.4
Forest grown	2.1	0.5	5.8	8.4
Seed trees, average	2.1	1.8	3.9	7.8
2 insurance trees per acre				
Old field, from seed trees	2.2	2.8	0.0	5.0
Forest grown, from seed trees	2.1	3.2	0.7	6.0
Forest grown, from strips	1.9	0.0	0.6	2.5
Insurance trees, average	2.0	1.0	0.5	3.5

This example is used to emphasize the constant attrition of large pines by lightning on an area basis. With many trees, the loss would be relatively small, but with progressively fewer numbers of trees per unit area the mortality rate increases until with 1 seed tree per acre all trees on 100 acres might theoretically be killed in a period of 50 years.

Wahlenberg[4/] reported the incidence of lightning for the United States to be 10 strokes per square mile of land area each year. With these data indicating 2 strokes per 100 acres per year, the incidence of lightning would be 12.8 strokes per square mile, or slightly higher than the nation's average.

Trees were killed by lightning on 11 of the 14 seed-tree areas and 11 of the 18 insurance-tree areas. Six of the 10 areas that did not have a lightning-struck tree contained standing trees for only 0.7 years or less. Of the 21 stands that contained trees for 1 year or more, 17 stands, or 80 percent, had trees killed by lightning.

The data on wind and other causes emphasize that wind damage is erratic. Heavy wind damage occurred among large insurance trees selected from the seed-tree stands, but no wind damage was found in smaller insurance trees selected from strip cuttings. The high rate of mortality from causes other than wind and lightning occurred immediately following logging during the regeneration period. After the stands were regenerated and reduced to insurance trees, the mortality rate from causes other than wind and lightning was greatly reduced.

4/ Wahlenberg, W. G. Longleaf pine. 429 pp., illus. Charles Lathrop Pack Forestry Foundation, Washington, D. C. 1946.

HURRICANE DAMAGE

On October 15, 1954, Hurricane Hazel passed over a wide area of the coastal plain. It was the first severe hurricane to strike the study area in many decades. Severe damage occurred in both seed-tree and insurance-tree stands. The even-aged management areas on the Experimental Forest were mostly in one block, permitting the south and southeasterly winds to sweep through the stands. Wind speeds were estimated between 80 and 100 miles per hour in this storm. Because of a scarcity of rainfall the trees were firmly rooted in dry soil, and most of the damaged trees broke under compression, usually within the first 2 logs of the 4- and 5-log trees. On wet areas a few trees upturned. Some of the trees left standing sustained internal damage and have broken with relatively light winds since the storm.

Damage was related to tree size and origin of the original stands. Large seed trees that were selected from old-field stands suffered the most severe damage. Smaller, forest-grown, insurance trees selected from seed trees were less heavily damaged, and the smallest forest-grown insurance trees selected from strip cuttings were damaged the least (fig. 2). This is the same relationship of mortality to stand origin and tree size as shown for normal wind damage in table 2.

The normal rate of mortality of seed-tree stands has been shown to be from 1 to 2 percent of the trees per year. In comparison, the losses from this one storm ranged from 8 to 78 percent of the board-foot volume and very nearly the same percentage losses apply to the number of trees (fig. 3).

DISCUSSION

The insurance-tree plan of leaving 2 trees per acre for an extended period of time is not recommended. Two trees per acre are usually inadequate to reseed an area following a wildfire, and wind and lightning progressively reduce this number. The individual surviving trees may grow rapidly in volume and value but within the young even-aged stands a small volume of quality saw-log material will be difficult to remove as products other than pulpwood until the young stand attains saw-log size. If this period is 35 years, lightning will reduce the number of insurance trees by 35 percent. During the first 15 to 20 years the insurance trees are also vulnerable to normal winds and, of course, hurricanes. If the hazards are so high that insurance is needed, many seed trees or one of the selection systems should be used, or provision should be made to plant areas destroyed by wildfires.

The timber value lost in seed trees during the regeneration period should be considered a cost of the seed-tree method. Tractor logging and drastic cultural treatments (disking, burning, and bulldozing) that improve seedbed conditions and reduce competition may increase the mortality of seed trees, but these measures are often essential to establish well distributed stands of seedlings. The number of seed trees that die from injury can be reduced by logging supervision and good judgment in the choice of cultural treatment. In any combination of logging method and cultural treatment the best

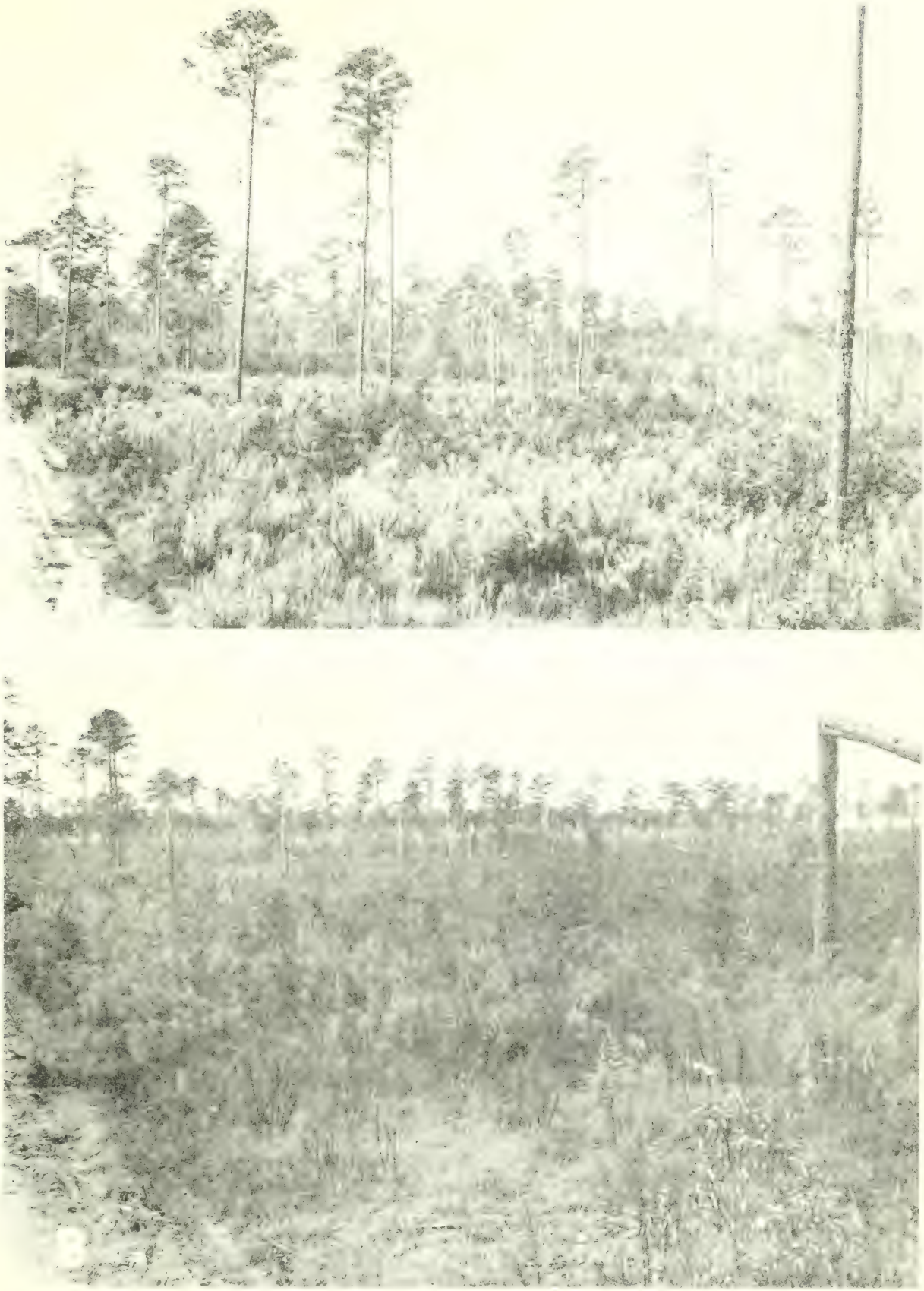

Figure 2.--A, Stand of 2 insurance trees per acre pictured October 1953, before the hurricane. B, Same stand October 1954, after the storm, showing typical breakage of main boles.

opportunity to reduce the mortality of seed trees will come with shortening the period that seed trees remain on the area.

Reducing the period of regeneration also permits the felling and removal of the large trees with a minimum of damage to the seedling stands. With planned skidroads and directional felling, seed trees can be removed from any young seedling stand with little damage except at yarding and loading points. If the trees are removed after seedfall, these areas generally reseed satisfactorily.

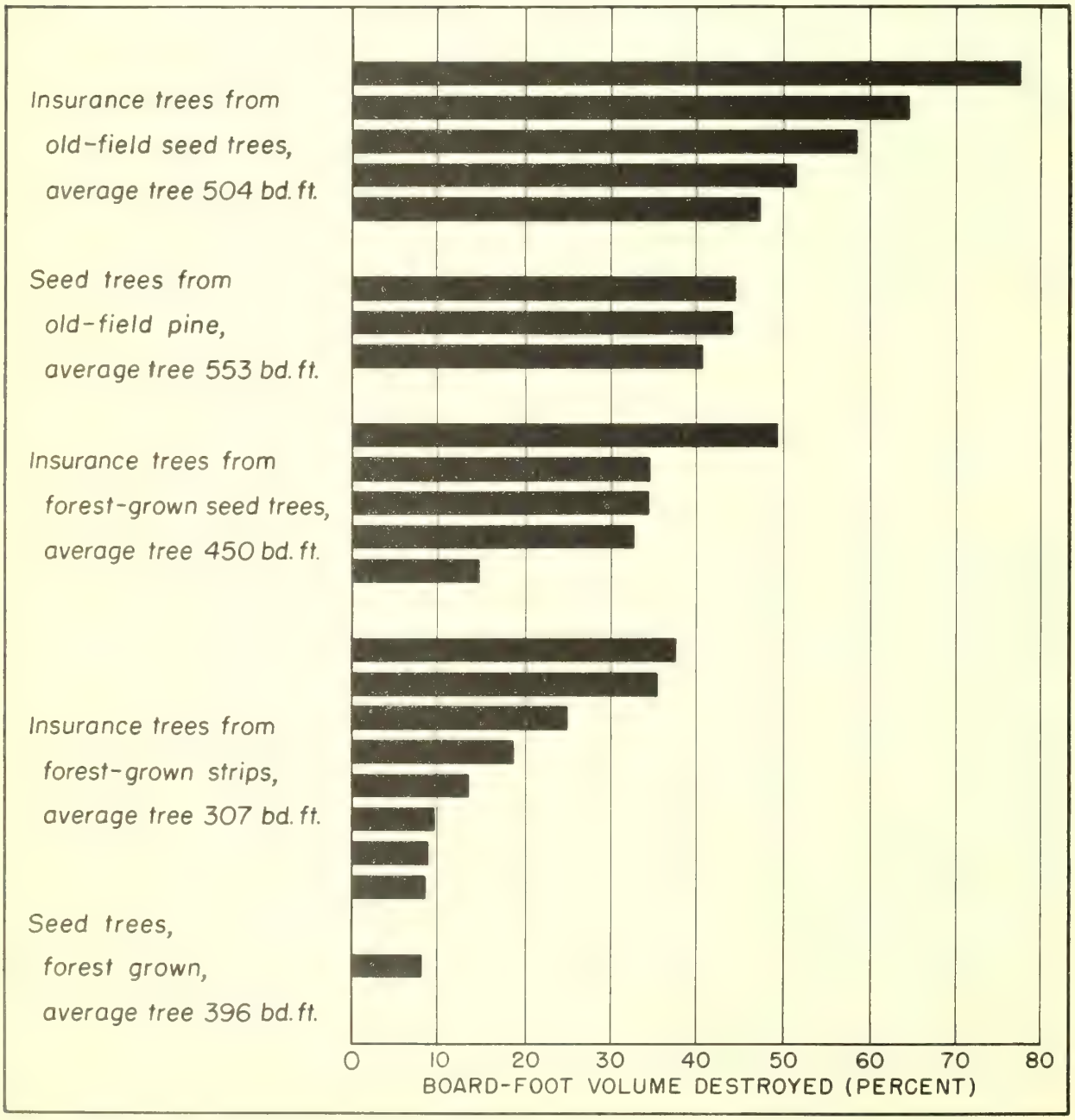
Insurance trees from old-field seed trees, average tree 504 bd. ft.
Seed trees from old-field pine, average tree 553 bd. ft.
Insurance trees from forest-grown seed trees, average tree 450 bd. ft.
Insurance trees from forest-grown strips, average tree 307 bd. ft.
Seed trees, forest grown, average tree 396 bd. ft.
0
10
20
30
40
50
60
70
80
BOARD-FOOT VOLUME DESTROYED (PERCENT)

Figure 3.--Percent of board-foot volume of pine seed or insurance trees destroyed on individual management areas by Hurricane Hazel.

The effective regeneration period for loblolly pine on cutover lands in the coastal plain is short, generally occurring the first year and seldom extending beyond 3 years. If an operable volume of the best trees is left to furnish seed and these trees are removed as soon as the effective regeneration period is over, the value of trees lost is small compared to costs of alternative methods of artificial seeding and planting.

SUMMARY

The 8 best seed-producing pines, or one-quarter of the pine stands, were left to reseed each acre when the timber was harvested from mature stands. Crawler tractors were used in logging. Cultural operations designed to improve the seedbed and reduce competition from undesirable plants were used on some of the areas. One-half of the logged areas were burned and one-quarter disked to improve the seedbed. Some seed trees were injured during the logging and in the burning operations. Eight percent of the seed trees were severely damaged in logging and 5 percent of the injured trees died.

A record of mortality showed that less than 1 percent of the seed trees died per year for all seed-tree areas during the average regeneration period of 3.3 years. The increased seed-tree mortality due to the burning treatment was approximately equal to the average lightning mortality for the period. A number of trees died with no external evidence of injury. Lightning and wind caused over half the mortality during the period the trees had to stand to reseed the area.

Following successful regeneration by the seed-tree and strip methods, all merchantable pine trees were cut except 2 sound and thrifty trees per acre left as an insurance measure. Few if any of these trees were injured by the relogging. During the 2.1-year period of record, 1.75 percent of the insurance trees died per year. Over 90 percent of the mortality was a result of lightning and wind.

The rates of mortality computed for 100 acres of seed trees or insurance trees for a period of 1 year indicate that lightning mortality is constant for a given area of land. Mortality caused by wind, tree injury, and other causes is proportional to the number of trees per unit area. The insurance-tree plan of leaving 2 trees per acre for an extended period of time is not recommended. Two trees per acre are usually inadequate to reseed an area following wildfire, and wind and lightning progressively reduce this number.

On October 15, 1954, a full-blown hurricane struck the forest, and seed-tree and insurance-tree stands were severely damaged. The loss from this one storm dwarfs all other mortality. During the 6 years 1948-1954, the annual mortality per 100 acres was 7.8 trees dying in seed-tree stands and 3.5 trees dying in insurance-tree stands. In comparable stands 239 seed trees and 65 insurance trees were destroyed on the average 100 acres by this hurricane.

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Influence of Loblolly Pine Overwood on Advance Reproduction

by

E. V. Brender and John C. Barber

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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INFLUENCE OF LOBLOLLY PINE OVERWOOD ON ADVANCE REPRODUCTION

By

E. V. Brender and John C. Barber

INTRODUCTION

At sporadic intervals, perhaps once each decade, a favorable combination of loblolly seed production and rainfall distribution occurs in the lower Piedmont region, with the result that pine seedling stands become established beneath overwood stands of loblolly pine. The majority of these understory pine stands are found on the flat ridge tops and on gentle to moderate slopes of southerly and westerly exposures. This advance reproduction occurs in more or less uniform age classes over contiguous areas from a few acres to as many as 100 acres, depending upon the uniformity of the topography.

The overstory stands may have a stocking of 120 square feet of basal area per acre and still have a solid understory stand of loblolly pine (fig. 1). Advance pine reproduction may also become established underneath stands as young as 20 years of age where the overwood is less than 60 square feet of basal area (fig. 2).

The occurrence of loblolly pine reproduction as an understory has great potential value to the landowner. He has only to give it reasonable care to insure the establishment of his future stand or parts of it. Regardless of the landowner's method of management, thousands of acres of seedlings become established in advance of the planned reproduction cut. This applies whether the stand is to be reproduced by leaving seed trees, or by the shelterwood method, or in openings created by selective cutting, or even where the plan specifies clear cutting and planting. Where this advance reproduction is present, the owner will not have to wait several years for the right combination of seedfall and rainfall, nor bear the expense of planting. In an effort to realize more fully the potential of this advance reproduction, a study was begun to determine the conditions under which these seedling stands become established and maintain themselves, and to determine the growth rates of the seedlings.

METHODS OF INVESTIGATION

The data were collected on and in the vicinity of the Hitchiti Experimental Forest, near Macon, Georgia, from 79 circular quarter-acre plots covering a range of loblolly pine overwood and understory conditions as follows:

Figure 1.--A stand of 8-year-old loblolly pine seedlings beneath an overwood of 120 square feet of basal area per acre.

Figure 2.--Stand of 5-year-old loblolly pine seedlings underneath a 22-year-old overwood of 60 square feet basal area.

Range of Plot Conditions

Overwood stand density	Stand density index (SDI) 23-298
Overwood stocking	12-158 sq. ft. basal area per acre
Overwood age	16-66 years
Overwood shade level	7-48 feet
Site index	36-92 feet at age 50
Average understory seedling ages	4-19 years
Average understory seedling heights	0.9-17.9 feet
Number of seedlings per acre	3,000-20,000

The appendix of this paper contains definition of SDI and conversion values of SDI to basal area.

All trees in the overstory of the quarter-acre plot were included to express degree of stocking. Five of the dominant or codominant trees on each plot were used to determine the age, site index, and average level of shade (height to base of live crown) of the overwood. Measurements of the pine understory were taken on alternate milacre quadrats extending in the four cardinal directions from the center of the quarter-acre plot. The understory data included age of seedlings, total height of dominant seedlings, degree of stocking, and seedling form.

This report first considers changes in the development of the overwood; then it deals with static relationships of advance reproduction under undisturbed conditions; and, finally, the more dynamic relationships in a growing forest are considered.

DEVELOPMENT OF THE OVERWOOD

Changes in Stocking

The annual rate of increase in SDI, or in basal area, depends principally upon the site, the degree of stocking, and to a lesser extent upon the age of the stand. The arithmetic average annual rate of growth for the average site with an index of 70 was found to be 4.5 SDI units, or 2.25 square feet of basal area per acre in stands which averaged 142 in SDI and 75 square feet in basal area at the outset of the 5-year measurement period. However, as we shall see later, the annual changes in SDI exert a relatively small influence upon the rate of development of the understory pine seedlings.

Changes in Crown Ratios and Levels of Shade

An important relationship of age and stand density to crown ratio of dominant and codominant trees was established in this study. The relationship is expressed by the following regression equation: [1/]

$$\text{Crown ratio} = 91.61 - 0.0685(\text{SDI}) - 0.8068(\text{age})$$

where

crown ratio = percent of live crown of the average dominant and codominant trees

SDI = stand density index

age = age of overwood

For each 10-year advance in age the crown ratio is reduced by 8 percent, while the estimated effect of increase in stand density during that period amounts to an additional average reduction in crown ratio of about 3 percent. This reduction results in raising the shade level of dominant and codominant trees. By applying the crown ratio values obtained from the equation to the average total height of dominant and codominant trees, and subtracting the resultant crown length from the total height, the principal level of shade of a stand can also be determined. Figure 3A and B shows the changes in crown ratio with age and density, and the corresponding changes in levels of shade on average sites. For example, the dominant and codominant trees in a 20-year-old open-grown stand of 40 SDI would have an average crown ratio of 73 percent. Ten years later at an SDI of 85, the average crown ratio would be 62 percent. The corresponding levels of shade would be 11 and 21 feet, respectively.

SURVIVAL AND GROWTH OF UNDERSTORY PINE

Survival and growth of advance pine reproduction depend upon the amount of overwood present and upon its level of shade.

Influence of Overwood Density

The influence which the overwood density exerts upon the development of advance pine reproduction varies for different seedling age classes. It is least important with young seedlings, but with older reproduction the influence of overwood density becomes increasingly important. For example, for 4-year-old seedlings a difference of 160 SDI units in overwood stocking is required to produce a difference of 1 foot in seedling height, while for 10-year-old seedlings only 36 SDI units are needed to produce the same difference.

Influence of Level of Shade of Overwood

The influence of overwood density on seedling behavior is only part of the story; of even greater importance is the level of shade of the overwood,

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1/ See Appendix for analysis of variance of independent variables.

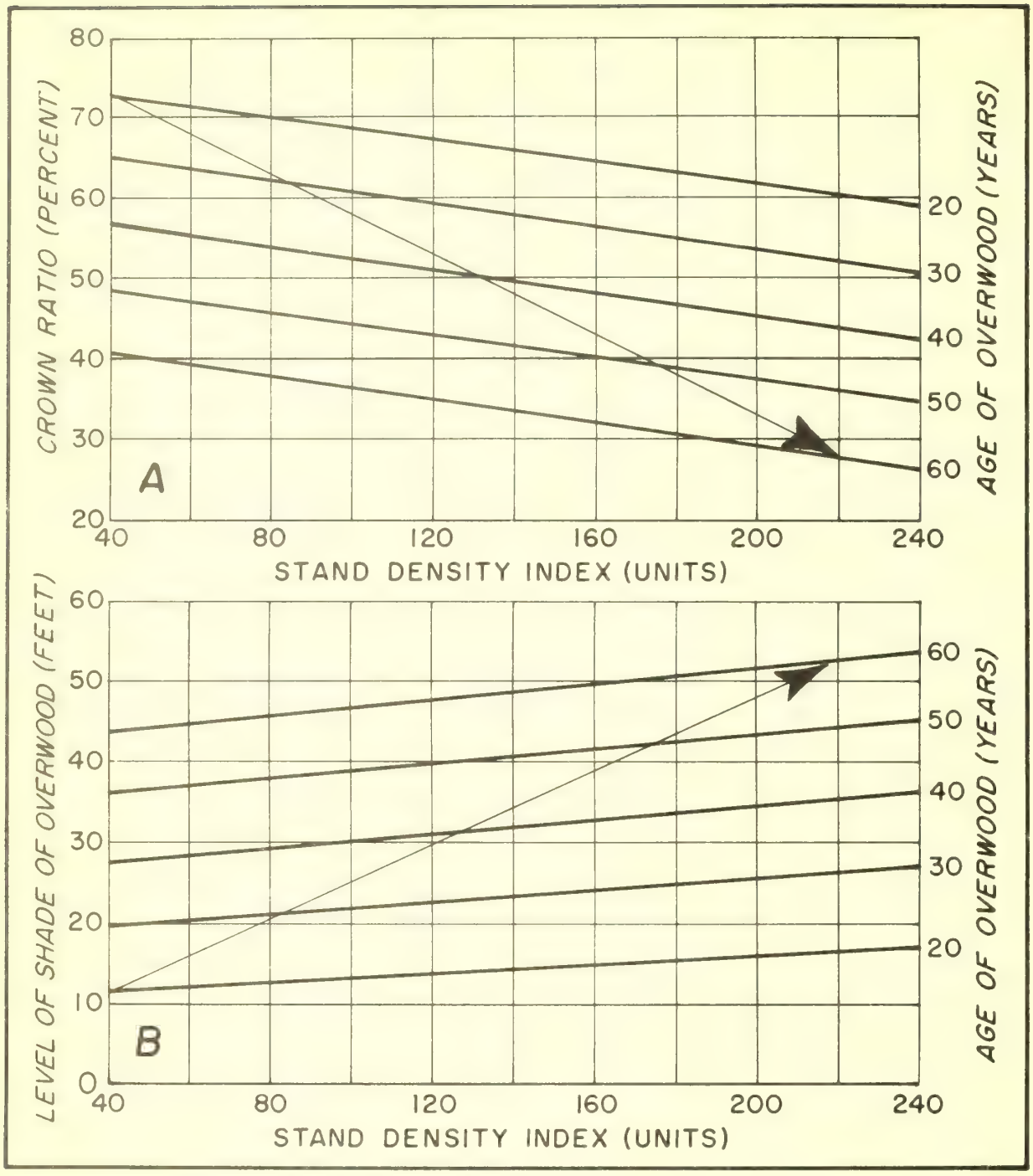

Figure 3.--The proportion of live crown of dominant and codominant loblolly pine trees, and the height to the base of their crowns depend upon their age and the stand density. This relationship at any given time, as determined by this study, is shown by the five parallel lines in these charts. With elapsed time, the change to be expected in crown ratio is shown by the arrow in chart A. The simultaneous change in shade level in the opposite direction is shown by the arrow in chart B.

as measured by the height to base of live crown. Survival and growth of the understory pine seedlings are poorest under low overwood shade. For instance, with a low shade level of 10 feet, well-stocked 4-year-old seedling stands were not found when the overwood SDI exceeded 140 units. With a high shade level of 40 feet, 4-year-old seedling stands were observed under an SDI of 300 units. Shade level also strongly influences understory seedling heights. For every 10-foot increase in level of shade, average seedling height is 0.7 foot greater.

Combined Effects of Overwood Density and Shade Level

The total effects of overwood density, level of shade, and seedling age can be expressed by the following equation: 2/

$$\text{Seedling height} = -4.9607 + 1.4620(\text{age}) + 0.0079(\text{SDI}) + 0.0696(\text{shade}) - 0.0036(\text{age})(\text{SDI})$$

where

seedling height is expressed in feet

age = age of understory in years

SDI = stand density index

shade = height of shade of the average lower limit of the crowns of dominant and codominant trees expressed in feet above ground.

A relatively small amount of overwood exerts a depressing effect on the height growth of understory seedlings. Even under a high shade level of 40 feet and an overwood density of only 40 SDI units, the average height of 4-year-old seedlings is only 63 percent that of free-growing seedlings. But, it takes a large increase in overwood density to bring about additional noteworthy reduction in seedling height growth. Even when the overwood density is 120 SDI units, the average 4-year-old seedling is still 52 percent as tall as a free-growing seedling (fig. 4A).

When comparing seedling heights attained under lower overwood shade levels with the height of free-growing seedlings, the contrast becomes progressively larger. For example, 4-year-old seedlings under a 20-foot shade level and under a stand of SDI 40 are only 38 percent as tall as free-growing seedlings (fig. 4B).

The survival of understory pine stands, as influenced by shade level and stand density, is also shown in these graphs. Under a low shade of 20 feet, and an overwood density of 220 SDI, no seedling stands above 6 years of age were encountered in this study; but with a high shade level of 40 feet, even 10-year-old seedling stands can maintain themselves under the above degree of stocking.

2/ See Appendix for analysis of variance of independent variables.

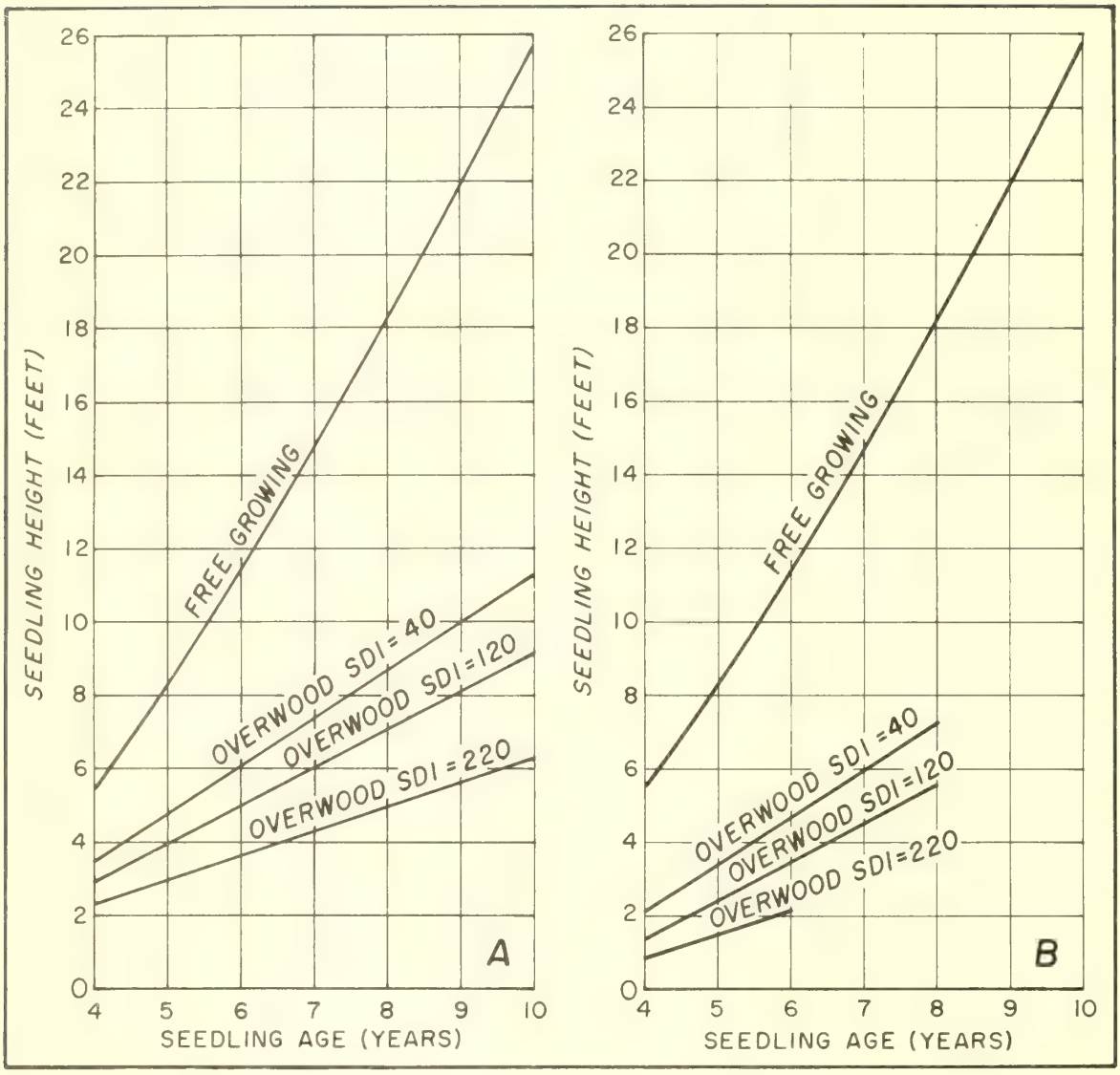

Figure 4.--Comparison of understory seedling heights at various ages and overwood densities with that of free-growing seedlings. A, At a high (40-foot) shade level. B, At a low (20-foot) shade level.

Concurrent Overwood and Understory Development

The information presented to this point has dealt with static forest conditions. In a growing forest, changes occur in the stand density of the overwood, in its level of shade, in the age of the understory seedlings, and the reaction of the seedlings to these changes.

Under average conditions, the overwood of loblolly pine stands in the lower Piedmont increases annually about 4.5 SDI units and the level of shade is raised about 1 foot. This annual rise in shade level, which is a favorable factor in understory seedling development, usually compensates, or more than compensates, for the influence of annual increase in overwood density. The development of advance pine reproduction in a given stand can be projected by inserting new values for progressive changes in the overwood and age of the understory seedlings in the formula developed for seedling heights.

This has been done in figure 5 for seedlings which originated under relatively high shade levels associated with a 50-year-old overwood at different initial degrees of stocking and an initial understory seedling age of 4 years.

In figure 5, where the density of the overwood was increased 27 SDI units and the shade level was raised 6 feet, the height growth of understory seedlings during the 6-year interval was 7.6, 5.8, and 3.7 feet with initial densities of 40, 120, and 220 SDI units respectively.

CONCLUSIONS

In the lower Piedmont, fully-stocked stands of advance reproduction survive and grow underneath a great range of overwood densities of loblolly pine. A relatively small amount of overwood markedly reduces the height growth of understory seedlings as compared with that of free-growing seedlings; but a rather large additional increase in overwood density is required to bring about significant additional reduction in seedling height growth. Thus, under the shelterwood method of regeneration, considerable leeway can be exercised in the amount of overwood left.

This study shows that level of shade ranks with overwood density as a major factor affecting the growth rate of loblolly pine seedlings. In fact, in a given stand, the progressive increase in shade level over a period of time has more effect on the growth rate of young seedlings than has the simultaneous increase in overwood density.

By cutting the limby, low-shade-level trees in thinnings and improvement cuttings, the average level of shade can be raised promptly. In addition, natural pruning, by virtue of increased age of the overstory trees, further raises the level of shade, which is a favorable factor in seedling survival and height growth. Where hardwood invasion is not a serious problem, relatively young open-grown stands of loblolly pine can be regenerated in the lower Piedmont by the shelterwood method without additional cultural measures, as soon as the overstory bears a good crop of seed. Early pruning in such open-grown stands would serve the dual purpose of improving the quality of the product and improving the environment for regenerating a new stand.

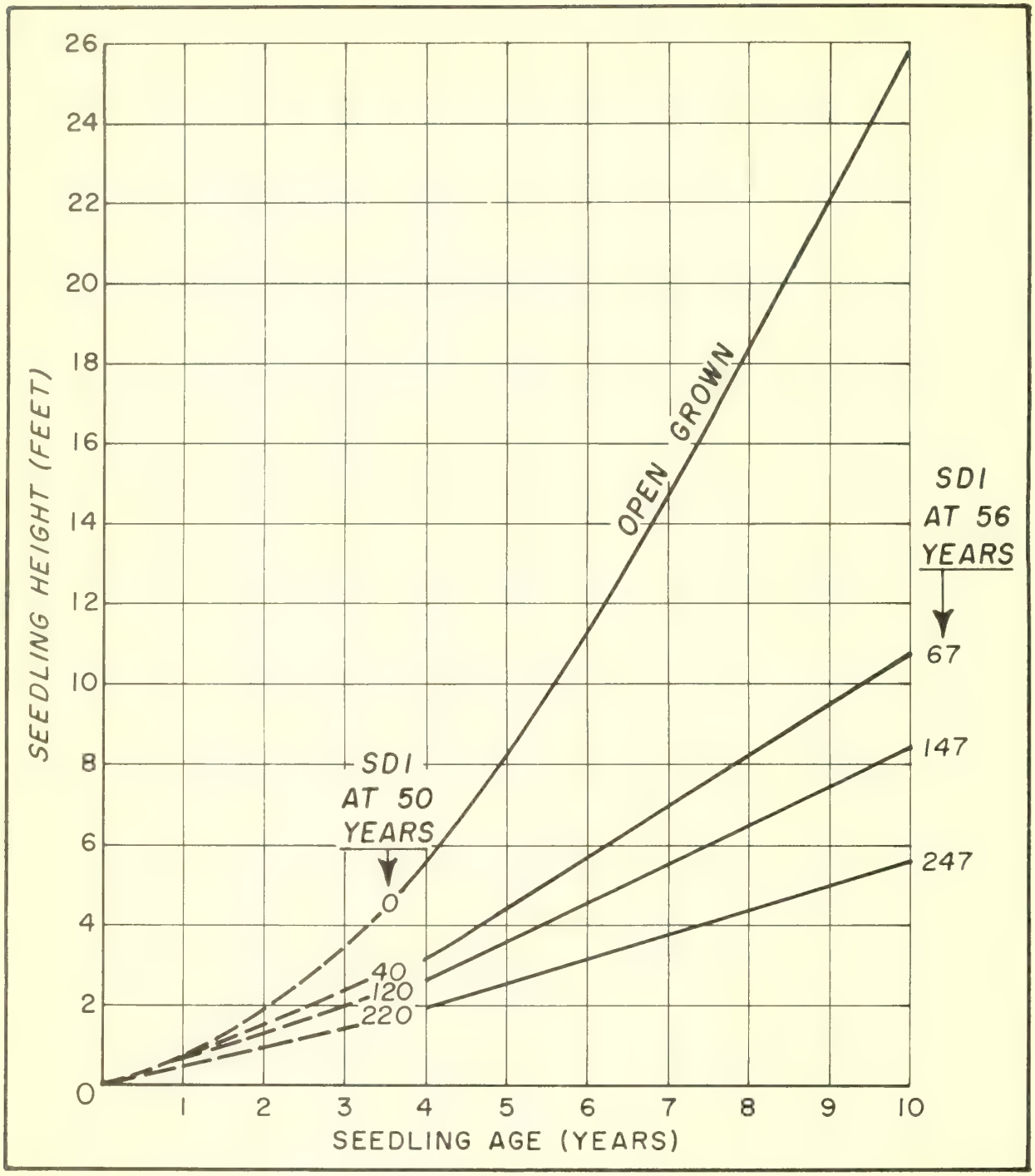

Figure 5.--Forecast of seedling height development in relation to progressive natural changes in a 50- to 60-year-old overwood at initial densities as shown on the chart and with a rise in shade level from 36 to 42 feet between 4 and 10 years.

APPENDIX

Stand Density Index

Stand density index, developed by Reineke, [3/] is a measure of the relative density of a stand. It is based on a logarithmic equation which evaluates number of trees per acre and average size of the individual tree. The index value is equal to the theoretical number of trees 10 inches d.b.h. which would be the equivalent stocking.

The set of factors below has been computed to determine the conversion values from SDI to basal area and vice versa.

Basal area in square feet = SDI x factor

Stand density index = basal area ÷ factor

Average d.b.h. of stand (Inches)	Factor for converting SDI to basal area	Average d.b.h. of stand (Inches)	Factor for converting SDI to basal area
6	0.445	13	0.605
7	.473	14	.623
8	.499	15	.640
9	.524	16	.657
10	.545	17	.673
11	.567	18	.688
12	.586	19	.703
		20	.717

Crown Ratio

The following equation was developed to express crown ratio of loblolly pine in undisturbed stands:

Crown ratio (%) = 91.61 - 0.0685(SDI) - 0.8068(age)

where

SDI = stand density index

and

age = age of overwood in years.

3/ Reineke, L. H. Perfecting a stand-density index for even-aged stands. Jour. Agr. Research 46(7): 627-638. 1933.

The independent variables were tested by analysis of variance as follows:

Source	d.f.	s.s.	m.s.	"F"
Effect of SDI	1	0.083738	-	19.03**
Added effect of age	1	.463225	-	105.28**
Residuals (error)	50	.220018	0.004400	
Total	52	.766981		

Seedling Height

The following equation was developed to express seedling height:

$$\text{Seedling height (feet)} = -4.9607 + 1.4620(\text{age}) + 0.0079(\text{SDI}) + 0.0696(\text{shade level}) - 0.0036(\text{age})(\text{SDI})$$

where

age = age of seedling in years

SDI = stand density index of overwood

and

shade level = height (feet) to base of live crown of overwood.

The independent variables were tested by analysis of variance as follows:

Source	d.f.	s.s.	m.s.	"F"
Effect of age	1	6.558019	-	484.**
Added effect of SDI	1	.229965	-	16.99**
Added effect of shade	1	.262082	-	19.36**
Added effect of (age)(SDI)	1	.145632	-	10.76**
Total due to regression	4	7.195698		
Residuals (error)	74	1.001751	0.013537	
Total	78	8.197449		

** Indicates significance at the 1-percent level.

Agriculture-Asheville

tation Paper No. 63 March 1956

PUBLICATIONS ON FOREST GENETICS, Southeastern Forest Experiment Station

compiled by

Keith W. Dorman

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

FOREWORD

This list covers publications in the field of forest genetics and related subjects from 1939 through 1955. The short abstracts present important conclusions. The list is arranged by years, each year alphabetically by author.

It is hoped that lists such as this will enable those interested in the subject field to keep informed of new developments. The difficulty of reading all material about forest genetics is indicated by the large number of publication outlets. The attached list contains 90 articles which appeared in 34 different outlets.

PUBLICATIONS ON FOREST GENETICS,

Southeastern Forest Experiment Station

compiled by

Keith W. Dorman

MINCKLER, L. S.
1939. Genetics in forestry. Jour. Forestry 37: 559-564.

Considerable confusion exists regarding the application of genetics to forestry practice in America. It is emphasized that we should apply all that is known about genetics until research establishes further facts.

MINCKLER, L. S.
1942. One-parent heredity tests with loblolly pine. Jour. Forestry 40: 505-506.

One-hundred five lots of 1-0 loblolly seedlings grown from the seed of widely differing parent trees were planted in a randomized block experiment. Fifth year survival and growth measurements showed no significant relation with any observable characteristics of adult mother trees. The data did show significant differences in both growth and survival of progenies from different mother trees.

MITCHELL, H. L.
1942. The development of a high-yielding strain of naval stores pine. Naval Stores Rev. 52(7): 10, 12, illus. Also, with title Vegetative methods offer promising short cuts in propagating the high-yielding pine trees, AT-FA Jour. 4(7): 8-9, illus.

Announces establishment and objectives of the project to develop a high-yielding strain of pine for naval stores use and gives progress for the first 6 months of work. Reports successful rooting of cuttings from very young trees.

MITCHELL, H. L.
1942. Development of high-yielding strain of naval stores pine. South. Forest Expt. Sta., South. Forestry Notes No. 45.

Brief statement on objectives and accomplishments of the project after about 6 months of work. Reports successful rooting of cuttings from very young trees.

MITCHELL, H. L.
1942. Studies regarding the development of a high-yielding strain of naval stores pine. Forest Farmer 1(11): 1, 3.

Brief statement of objectives and progress. Abstract of paper presented before Southern Forestry Conference of 1942.

MITCHELL, H. L., SCHOPMEYER, C. S., and DORMAN, K. W.
1942. Recent developments in the selection and propagation of high-yielding naval stores pine. South. Forest Expt. Sta., South. Forestry Notes No. 46.

Summarizes the progress and accomplishments after about the first year of work. Superior trees producing from two to three times the yield of gum from average trees were located, and cuttings from mature slash pine trees were successfully rooted.

MITCHELL, H. L., SCHOPMEYER, C. S., and DORMAN, K. W.
1942. Pedigreed pine for naval stores production. Science 96: 559-560.

Describes work on the project and accomplishments in selection where trees producing from two to three times as much gum as average trees were located. Also reports on experiments in vegetative propagation and details of method used to root cuttings from mature trees.

CURRY, J. R.
1943. Selection, propagation, and breeding of high-yielding southern pine for naval stores production. Jour. Forestry 41: 686-687.

Efficiency in naval stores production has been decreasing and competition is stronger. Development of a high-yielding strain is advanced as a means of increasing tree yields and efficiency of labor. Work is progressing along three lines: (1) selection of superior trees, (2) vegetative propagation experiments, and (3) controlled breeding.

SNOW, A. G., Jr., DORMAN, K. W., and SCHOPMEYER, C. S.
1943. Breeding blueblood pines. AT-FA Jour. 5(6): 8-10, illus.

Flowering characteristics of slash pine and the importance of using good breeding stock in the development of superior pine trees are given.

SNOW, A. G., Jr., DORMAN, K. W., and SCHOPMEYER, C. S.
1943. Developmental stages of female strobili in slash pine. Jour. Forestry 41: 922-923, illus.

Early growth and development of the female flower is divided into four stages: (1) suitable for placing pollination bags; (2) latest stage for bagging; (3) optimum for pollinating; (4) beyond receptive stage, and bags may be removed.

DORMAN, K. W., SCHOPMEYER, C. S., and SNOW, A. G., Jr.
1944. Top bracing and guying in the breeding of southern pines. Jour. Forestry 42: 140-141, illus.

Breeding or other work in the tops of slash and longleaf pine can be made safer and easier by reinforcing the upper part of the central stem with 2x2-inch splints and by the use of three guy wires from the top of the tree to the ground.

DORMAN, K. W.
1945. High-yielding turpentine orchards--a future possibility. The Chemurgic Digest 4: 293, 295-299, illus.

Development of a high-producing strain is offered as a solution to many of the problems of the naval stores industry. Superior trees have been located, methods have been developed for vegetative propagation of slash pine, and controlled breeding with superior trees has been carried out. It is estimated that yields can be increased from the present average of 166 pounds per acre to 3,500 pounds by the use of superior trees grown in well-managed, fully-stocked stands.

MINCKLER, L. S.
1945. Seed source. Is it taken seriously? Jour. Forestry 43: 749-750.

Data collected on shortleaf and loblolly seed source for forest nurseries of 12 states show a lack of progress in obtaining a satisfactory seed source. Absence of a sound policy is attributed to lack of conviction that source is of real importance and to the conflict between technical considerations and administrative efficiency.

DORMAN, K. W.
1946. The life history of slash pine. National Container Digest 2(10): 1, 4, 5, illus.

Development of female flowers, seeds and slash pine trees for one life cycle is discussed.

DORMAN, K. W.
1947. Pedigreed pines for Dixie's future forests. Forest Farmer 6(8): 7.

An outline of work already begun for producing a better pine for southern forests. This includes selection of superior breeding stock, vegetative propagation to preserve the valuable traits of the stock, controlled breeding and further selection to combine the desirable characteristics of two or more trees into one tree or to increase some desirable characteristic, and the checking of performance of the progeny.

DORMAN, K. W.

1947. Rooted pine cuttings make rapid growth. AT-FA Jour. 9(11): 8, illus.

Slash pine cuttings rooted in the greenhouse and then planted in the field grow rapidly. Within 3 or 4 years from the parent tree they grow to be trees 6 feet or more in height.

DORMAN, K. W.

1947. Longleaf pine cuttings rooted in greenhouse. Jour. Forestry 45: 594.

Longleaf pine cuttings from large trees were rooted for the first time. The most effective treatment consisted of soaking the bases of the cuttings for 24 hours in a water solution containing 15 p.p.m. traumatic acid, 15 p.p.m. sodium pentachlorophenate, 10 p.p.m. vitamin B_1, 5 percent sucrose, and 0.4 percent of a commercial plant food.

DORMAN, K. W.

1947. Progress in breeding better turpentine pines. AT-FA Jour. 9(12): 10, 15, illus.

The controlled-breeding work of 1943 and 1944 with slash pine resulted in enough seed to produce 600 seedlings. These were set out in a plantation in 1946. Each of these seedlings has a carefully recorded pedigree. The plantation includes crosses of high-yielding turpentine pines, average-yielding trees, and some slash-loblolly and slash-longleaf hybrids. When the seedlings are large enough, the gum-yielding capacity of the different groups will be compared by small-scale chipping methods.

DORMAN, K. W.

1947. Better pines for turpentining. American Forests 53: 498-500, illus.

In the rubber industry production efficiency was greatly increased by the use of superior trees obtained by controlled breeding. On the other hand, the pine gum industry in America is suffering from decreasing efficiency. This article is a popular account of selection and breeding work, similar to that done with the rubber tree, designed to increase the efficiency of the gum industry by developing a strain of high-yielding trees which will greatly increase yields per acre with little additional labor.

DORMAN, K. W.

1947. Breeding better southern pines for the future. South. Lumberman 175(2201): 147-150, illus.

A popular account of the work in tree selection, breeding and vegetative propagation of southern pines. In a concluding section the author speculates on the gum yields possible from a plantation of cuttings from known superior trees. The greater gum yield of these trees and better stocking of the plantation could yield 24 times as much gum per acre as the present average acre of turpentine timber.

DOWNS, Albert A.

1948. How pine cuttings are rooted. Forest Farmer 7(5): 26, illus.

Important factors in rooting cuttings of slash and longleaf pine are treatment with a growth regulator, such as traumatic acid, and a carefully controlled environment. Cuttings must be sprayed intermittently with water during the daylight hours to prevent desiccation.

HEPTING, George H., and TOOLE, E. Richard

1948. Wilt epidemiology and resistance in the mimosa tree. (Abs.) Phytopath. 38: 13.

The wilt has spread from Maryland to Florida in the 12 years since it was discovered in North Carolina. Occasional seedlings have resisted the wilt following several severe inoculations. Twenty-eight resistant clones are now available. Cuttings from these are also highly resistant.

TOOLE, E. Richard

1948. Rootability of cuttings. American Nurseryman 88(2): 72.

Rooting tests with the mimosa tree showed that in the case of stem cuttings the nearer the root system the cuttings were taken the better they rooted, indicating increased content of rooting hormone as one progresses from branch tip to branch-to-stem and down the stem.

CLAPPER, Russell B., and MILLER, John M.

1949. Breeding and selecting pest-resistant trees, USDA Yearbook, Trees: 465-471. Washington, D. C.

A general discussion of attempts to breed for resistance to tree diseases and insects in the United States.

DOWNS, Albert A.

1949. Unusual tree appears in breeding tests. Forest Farmer 9(2): 8, illus.

During a dry period the needles of one tree in a slash pine gum-yield progeny test develop alternating rings of bright yellow and dull green. From a distance, this 4-year-old tree appears bright yellow. In drought periods the surrounding trees turn a uniform dull yellowish green. The unusual tree appears in no danger of dying. When a drought ends, the tree gradually regains a healthy green color.

DOWNS, Albert A.

1949. Developing better pines for gum production. South. Lumberman 179(2249): 233-236, illus.

Accomplishments of 8 years' work by the Lake City Branch of the Southeastern Forest Experiment Station toward the development of a high-yielding strain of naval stores pine are reported. A dozen trees have been found which produce at least twice as much gum as the average of the trees around them. Breeding work with these trees and with trees of average and low yield capacity has been designed with the aim of creating superior trees and supplying information on the manner in which

the high-yielding characteristic is inherited. One progeny test plantation of 600 trees is now 4 years old, and 800 one-year-old seedlings are available to establish another progeny test plantation. Methods of rooting pine cuttings have been developed. For trees of working size, 5 to 20 percent of the cuttings root. Cuttings from very young trees root more easily.

DOWNS, Albert A.

1949. Low forking in white oak sprouts may be hereditary. Jour. Forestry 47: 736.

In 30 clumps of sprouts in a 25-year-old stand in the Piedmont of Virginia in which the largest stem was forked, 53 percent of the next largest stems were also forked. In 102 clumps in which the largest stem was straight, all but 4 percent of the next largest stems were also straight. A chi-square test of the ratios showed that this difference was significant. Only stems definitely forked below 24 feet were classed as forked; all others were classed as straight or not forked.

JACKSON, L. W. R., and ZAK, Bratislav

1949. Grafting methods used in studies of the littleleaf disease of shortleaf pine. Jour. Forestry 47: 904-908, illus.

In transmission experiments with littleleaf disease both the above-ground parts and the roots of shortleaf pines were successfully grafted with seedlings, saplings, and adult trees serving as stock trees. The bark-patch method proved highly successful. The approach grafting method although not quite as successful as the first method, did, nevertheless, give a fair percentage of graft unions for both stems and roots. Thus far, healthy trees receiving the grafts have not developed symptoms of the disease.

TOOLE, E. Richard

1949. Selection and propagation of wilt-resistant mimosa trees. Trees 9(4): 10, 12, 16, illus.

Describes the wilt resistance found in the mimosa tree as mentioned in earlier articles, and also gives directions for rooting cuttings of root pieces for propagation of resistant clones.

TOOLE, E. Richard, and HEPTING, George H.

1949. Selection and propagation of Albizzia for resistance to Fusarium wilt. Phytopath. 39: 63-70, illus.

In testing certain species of Albizzia, mainly A. julibrissin, for resistance to Fusarium wilt, 1437 seedlings have been grown from seed collected at various locations from Maryland to Louisiana, and their roots inoculated. Twenty of these trees have survived the disease as long as 8 years, despite repeated inoculations, and in the more recent experiments many more have survived for shorter periods. Fifty-six percent of the seedlings grown from seed resulting from uncontrolled pollination of the resistant selections were wilt-resistant.

All cuttings rooted from the resistant selections have thus far appeared immune to the wilt despite successive inoculations, while rooted cuttings from neighboring nonresistant wildlings became diseased and died following inoculation.

CLAPPER, Russell B.
1950. Breeding new chestnuts for southern forests. Forest Farmer 9(11): 8, illus.

Gives a brief history of the chestnut blight, the search for resistance among Oriental chestnuts, descriptions of some of the better Oriental types, and also mentions the breeding and hybridizing program of the USDA and some of the promising results. Discusses the problems of mass-producing resistant chestnuts.

DORMAN, K. W.
1950. The genetics of southern pines (a preliminary report). Southeast. Forest Expt. Sta., 52 pp., illus.

A discussion of phytogeny of gymnosperms, classification of pines, mechanism of pollination, development of the seed, controlled-breeding methods, and variation in wild stands.

DORMAN, K. W.
1951. We need better seed collecting equipment. U. S. Forest Service, Tree Planters' Notes 5: 2.

A brief discussion of the need for improved equipment for tree climbing and cone picking.

CLAPPER, Russell B.
1952. Relative blight resistance of some chestnut species and hybrids. Jour. Forestry 50: 453-455, illus.

Summarizes 25 years of selecting and breeding, including hybridization, among American chestnuts and chinquapins, and blight-resistant Oriental chestnuts. Describes some promising progeny from this work.

CLAPPER, R. B.
1952. Breeding and establishing new trees resistant to disease. Econ. Bot. 6: 271-293.

A review of the USDA program of selecting, breeding, and testing chestnuts resistant to blight among a wide range of species of Castanea.

COMMITTEE on Southern Forest Tree Improvement (C. E. Ostrom, Chairman)
1952. Suggested projects in the genetic improvement of southern forest trees, Southeast. Forest Expt. Sta. Paper 20, 12 pp.

Projects are listed in: (1) application of genetics to the collection of seed for planting, (2) geographic source of seed for forest planting, (3) improvement of southern forest trees through selection and breeding, (4) techniques and basic aspects of forest genetics such as

selection, anatomical studies, breeding, methods for control of flowering and fruiting, methods of vegetative propagation, and equipment for tree improvement work.

DORMAN, K. W.
1952. Hereditary variation as the basis for selecting superior forest trees. Southeast. Forest Expt. Sta. Paper 15, 88 pp., illus.

A comprehensive discussion of the basis for heritable variation and selection in tree improvement and silviculture.

DORMAN, K. W.
1952. Directory of forest genetics activities in the south. Southeast. Forest Expt. Sta. Paper 17, 17 pp.

Lists by administrative agency work now under way in tree introduction, racial variation, selection and hybridization, vegetative propagation, cytology, and stimulation of seed production.

HEPTING, George H., TOOLE, E. Richard, and BOYCE, John S., Jr.
1952. Sex and compatibility in the oak wilt fungus. Plant Dis. Rptr. 36: 64.

The oak wilt fungus is described as hermaphroditic, self-sterile, interfertile, and of two compatibility types. A fungus thallus of either compatibility type can function as a male or female, but will mate only with the opposite compatibility type.

HEPTING, George H., TOOLE, E. Richard, and BOYCE, John S., Jr.
1952. Sexuality in the oak wilt fungus. Phytopath. 42: 438-442, illus.

The experimental data on 28 isolates of the oak wilt fungus that prove the preceding article on sex and compatibility are presented. Ways are described by which the two compatibility-type constitution of the fungus can be used to forward oak wilt research. A single tree usually has only one type (A or B), but occasionally a tree has both types in its vascular system. The types can be identified by the success or failure of spermatization with tester cultures of known type.

LITTLE, Elbert L., Jr., and DORMAN, K. W.
1952. Geographic differences in cone opening in sand pine. Jour. Forestry 50: 204-205.

The suggestion is made that typical sand pine with closed cones be called Ocala sand pine or Ocala race, whereas that occurring in western Florida with open cones be called Choctawhatchee sand pine or Choctawhatchee race.

LITTLE, E. L., Jr., and DORMAN, K. W.
1952. Slash pine (Pinus elliottii), its nomenclature and varieties. Jour. Forestry 50: 918-923, illus.

A discussion of the nomenclature of slash pine with the recommendation that the pine in the United States be separated from the Caribbean pine and that a new variety, South Florida slash pine, be recognized.

TOOLE, E. R.

1952. Two races of Fusarium oxysporum f. perniciosum causing wilt of Albizzia spp. Phytopath. 42: 694

Describes two forms of mimosa wilt fungus, one attacking A. julibrissin and one attacking A. procera (Puerto Rico).

BARBER, J. C.

1953. Tree planting at the Bent Creek Experimental Forest. Southeast. Forest Expt. Sta. Paper 27, 11 pp., illus.

A report on the survival and growth of experimental plantings, including the arboretum established in 1926.

DOOLITTLE, Warren T.

1953. Growth and survival of hybrid poplars. South. Lumberman 187(2345): 178-179, illus.

Growth of 12 clones planted in 1935 indicates that certain hybrid poplars on good sites in the Southern Appalachians grow faster than the most rapid-growing native species such as white pine, yellow-poplar, or northern red oaks.

DORMAN, K. W.

1953. A taxonomic study of slash pine. (Abs.) Assoc. South. Agr. Workers Proc. 50: 116-117.

Slash pine, one of the most valuable southern pines, is a distinct species from Caribbean pine, with which it has usually been united. The related pine of southern Florida is now recognized as a botanical variety.

DORMAN, K. W., BAUER, E., and GREENE, J. T.

1953. Tree improvement makes a step ahead. South. Lumberman 187(2345): 170-171, illus.

A description of the history and progress of the tree improvement program at the Ida Cason Callaway Foundation, Hamilton, Georgia. Reports variation in vigor of open-pollinated progeny of slash and loblolly pine maternal parents.

MERGEN, F.

1953. Gum yield in longleaf pine inherited. Naval Stores Rev. 62(47): 18-19, illus. Also, with title Gum yields in longleaf pine are inherited, Southeast. Forest Expt. Sta. Research Note 29, 2 pp., illus. Also in AT-FA Jour. 15(5): 14-17, illus.

First evidence that gum-yielding capacity is inherited is obtained from 17-year-old progeny test.

MERGEN, F.

1953. The story of some unique trees. South. Lumberman 186(2329): 72, 74.

For the first time in history, mature cones were collected from rooted slash pine cuttings. In addition to being a historical " first" it represents one step closer to the goal of developing high-yielding pines for naval stores.

MERGEN, F.

1953. Selection and breeding of slash and longleaf pine at Lake City, Florida (in English). Zeitschrift fur Forstgenetik und Forstpflanzenzuchtung 2(6): 126-129, illus. Frankfurt, Germany. Also in Internatl. Union Forest Res. Organ. Cong. (Proc.) 11: 481-487. Pub. 1954. Also, with title Selection and breeding of longleaf pine, in Naval Stores Rev. 63(7): 12-14, 23-26, illus.

Research in species improvement of longleaf and slash pine at the Lake City Research Center includes tree selection, vegetative propagation, and controlled breeding. Preliminary results are discussed.

MERGEN, F.

1953. First mature cones collected from rooted slash pine cuttings. AT-FA Jour. 15(10): 8-9.

Beginning with the rooting of cuttings in 1943-44, this is the first recorded production of mature cones from rooted slash pine.

MERGEN, F.

1953. Air-layering as a possible method to reproduce selected slash pine. Naval Stores Rev. 63(21): 19, 20, illus.

Long known to horticulturists as a method of reproducing cultivated plants, air-layering has been used successfully for the first time on slash pine.

MERGEN, F., and POMEROY, K. B.

1953. Some practical suggestions for better slash pine seed. The South. Lumber Jour. 57(11): 88-89, illus.

Organizations with extensive reforestation programs might improve seed quality in slash pine by improving selected natural stands of vigorous, even-aged, cone-bearing trees. Method of improvement and hints for seed collection are discussed.

OSTROM, C. E.

1953. More and better trees: the activities of the Committee on Southern Forest Tree Improvement. South. Lumberman 186(2326): 35-36. Also, with title Accomplishments of the Committee on Southern Forest Tree Improvement, in Naval Stores Rev. 62(51): 14-15, 26-28, illus. Also, with title Recent developments in the southern forest tree improvement program, (Abs.) Assoc. South. Agr. Workers Proc. 50: 115-116.

Discussion of the function, accomplishments, and plans of the Committee on Southern Forest Tree Improvement.

POMEROY, K. B.

1953. Tree improvement--its potentialities. Forest Farmer 12(11): 8, 9, 11, illus. Also in The Unit 48: 25-27, illus. Also in Paper Trade Jour. 137(6): 18-19, illus.

Preliminary results show that the value of forest trees can be increased by genetic control of inherited characteristics. Best returns in forest tree improvement will probably be achieved by combined efforts of silviculturists working with environmental factors and geneticists working with inherited factors.

POMEROY, K. B.

1953. Research in tree improvement at Lake City, TAPPI 36(11): 147a-150a.

Forest managers who remove undesirable trees, leave only the best trees for regeneration, and plant seedlings from the best available local parentage can reap the benefits of eugenic forestry while waiting for the deferred benefits of controlled breeding.

POMEROY, K. B.

1953. Better trees for tomorrow. Naval Stores Rev. 63(20): 19, 21-22. Also in AT-FA Jour. 16(2): 18.

Propagation and controlled breeding, proven tools of the horticulturist and agronomist, are now being used in developing superior strains of longleaf and slash pine.

SCHOPMEYER, C. S.

1953. The characteristics of a high gum-yielding tree. Naval Stores Rev. 63(12): 12-13, illus. Also in AT-FA Jour. 15(10): 4, illus. Also in Southeast. Forest Expt. Sta. Research Note 39, illus.

The factors controlling gum flow in slash pine appear to be size of resin ducts exposed by chipping, number of ducts per square inch of fresh face, viscosity of gum, and exudation pressure. If these factors are inheritable, trees rating high on all four can be developed by controlled breeding.

WENGER, K. F.

1953. The effect of fertilization and injury on the cone and seed production of loblolly pine seed trees. Jour. Forestry 51: 570-573, illus.

Application of fertilizer at the rate of 25 and 50 pounds per tree significantly increased cone production of 25-year-old loblolly pines. Forty-year-old trees did not respond to treatment. Half-girdling with a knife produced no increase in cone crop. Treatments did not significantly affect percentage of defective cones, number of seeds per cone, or percentage of defective seed per cone.

ZAK, B.

1953. Developing littleleaf-resistant shortleaf pine. South. Lumberman 187(2345): 147-149, illus.

Healthy and vigorous individual trees have been found surrounded by dead and dying trees. Potted seedlings show variable susceptibility to fungus attack when inoculated. Open-pollinated seed has been collected from apparently healthy trees. Also, these trees have been cross pollinated. Seed from more than a dozen localities over the range of shortleaf pine has been planted on severe littleleaf areas in Virginia, South Carolina, and Georgia in a test of racial variation in disease resistance. A number of selected trees have been propagated by grafting. A method of testing potted seedlings against Phytophthora cinnamomi within 2 years has been developed; also, a shorter method using seedlings growing in liquid solutions.

HEPTING, G. H.

1954. Gum flow and pitch soak in Virginia pine following Fusarium inoculation. Southeast. Forest Expt. Sta. Paper 40, 9 pp., illus.

Describes gum yields and amount of pitch-soaking in Virginia pine following inoculations with the pitch canker fungus.

HOEKSTRA, P. E.

1954. New blood for southern pines. South. Lumberman 189(2369): 182-183, illus.

Nonindigenous species and varieties of pine are being established in Florida to furnish material for tree improvement.

LITTLE, E. L., Jr., and DORMAN, K. W.

1954. Slash pine (Pinus elliottii) including South Florida slash pine, nomenclature and description. Southeast. Forest Expt. Sta. Paper 36, 82 pp., illus.

A report on the botanical basis for a recent change in scientific nomenclature.

McGREGOR, W. H. D., COWAN, D. R., and SPURR, S. H.

1954. Three races of scotch pine compared in southeastern Michigan. U. of Mich., Dept. Forestry, Michigan Forestry No. 5, 2 pp.

The trees from northern Europe grow more slowly but have better form than those from central Europe.

MERGEN, F.

1954. Grafting succulent slash pine scions. Southeast. Forest Expt. Sta. Research Note 59.

The discovery that scions can be grafted in the succulent stage promises to prolong the grafting season by several months.

MERGEN, F.

1954. Variation in 2-year-old slash pine (P. elliottii var. elliottii) seedlings. Southeast. Forest Expt. Sta. Research Note 62.

Survival of seedlings from all five geographic seed sources in Florida was high, but the growth of one from Polk County was low.

MERGEN, F.

1954. Self-fertilization in slash pine reduces height growth. Southeast. Forest Expt. Sta. Research Note 67.

Self-pollination tends toward poor seed set, low germination, reduced vigor, deformed growth, retarded flowering, or some degree of albinism.

MERGEN, F.

1954. Heteroplastic micrografting of slash pine. Southeast. Forest Expt. Sta. Paper 47, 17 pp., illus.

A project in grafting 1- to 6-month-old slash pine seedlings onto other coniferous species such as white spruce, white pine, ponderosa pine, and others.

MERGEN, F.

1954. Improving the early growth of longleaf pine. Naval Stores Rev. 64(3): 12, 13, 21. Also in Forest Farmer 13(11): 8, 9, 16, 17, illus.

Some 261 slash-longleaf pine hybrids have been produced for possible use in reforestation of dry sites.

MERGEN, F.

1954. Vegetative propagation techniques for genetics studies of slash pine (Pinus elliottii, Engelm.). American Soc. Plant Physiol. Program for the 29th Annual Meeting, pp. 6-7.

Review of techniques covered in more detail in other publications.

MERGEN, F.

1954. Mechanical aspects of wind-breakage and wind-firmness. Jour. Forestry 52: 119-125, illus.

Crown thinning and early improvement cuttings increase the exposure of young stands to wind pressure; in response the trees become more wind-firm and less susceptible to storm damage.

MERGEN, F.

1954. Inheritance of oleoresin yield in slash pine. AT-FA Jour. 17(2): 16-18, illus. Also in Naval Stores Rev. 64(9): 8, 9, 20, illus.

A test of the progeny from parent trees selected for high-gum production showed that gum-yielding ability is inherited.

MERGEN, F.

1954. Anatomical study of slash pine graft unions. Quart. Jour. Florida Acad. Sci. 17: 237-245, illus.

An anatomical study of the sequence of the knitting of a union in young slash pines showed that parenchymatous cells of medullary rays, phloem, cortex, and cambium participated in bridging the space between stock and scion tissues. The stock contributed the greatest part of the wound tissue, but the scion took part in callus formation. A continuous bridge between respective anatomical parts of the graft partners was apparent after 6 weeks.

MERGEN, F., and HOEKSTRA, P. E.

1954. Germination differences in slash pine from various sources. South. Lumberman 189(2364): 62, 64, 66.

Real differences are indicated in seed characteristics from collections in different locations.

MERGEN, F., and POMEROY, K. B.

1954. Tree improvement research at the Lake City, Florida, research center, a project analysis. Southeast. Forest Expt. Sta. Paper 45, 59 pp., illus.

Superior attributes sought are rapid growth, disease resistance, better stem form, and improved grain or density of wood.

MERGEN, F., and POMEROY, K. B.

1954. Suggestions for better slash pine seed. Forest Farmer 13(5): 6-7, 15, illus.

Directions for selection and reservation of trees capable of producing superior seeds in quantity.

MERGEN, F., and ROSSOLL, H.

1954. How to root and graft slash pine. Southeast. Forest Expt. Sta. Paper 46, 22 pp., illus.

A graphic exposition of new techniques for asexual propagation of pines useful as breeding stock (45 drawings).

POMEROY, K. B.

1954. Better trees for tomorrow. Florida Grower and Rancher 17(2): 12, 34.

General review of the possibilities of improvement of southern pine trees through genetic research.

POMEROY, K. B.

1954. Looking ahead with naval stores. Forest Farmer 13(12): 14, 18.

Discussion of future trends in the naval stores industry, describing the part to be played by high-yielding strains of pine.

SCHOPMEYER, C. S., MERGEN, F., and EVANS, T. C.

1954. Applicability of Poiseuille's Law to exudation of oleoresin from wounds on slash pine. Plant Physiol. 29: 82-87, illus.

The variables in a modification of the equation for Poiseuille's Law for the flow of liquids through capillaries were measured in the resin duct system of 12 slash pine trees (Pinus elliottii Engelm. var. elliottii). The modified equation is given.

ZOBEL, B., DORMAN, K. W., PERRY, T., GARIN, G., and WEISEHUEGEL, E. G.

1954. The role of genetics in southern forest management. Forest Farmer 14(1): 4-6, 14-15, illus., 14(2): 8, 9, 14-19, illus., 14(3): 8, 9, 14-15, illus.

I. Environment is the most important factor in tree development only within definite genetic limits.

II. Seed collection for forest nurseries must be from the most favorable geographic origin.

III. In reserving seed trees, select superior individuals insofar as possible.

BARBER, J. C., DORMAN, K. W., and JORDAN, R. A.

1955. Slash pine crown width differences appear at early age in 1-parent progeny tests. Southeast. Forest Expt. Sta. Research Note 86.

Crown-width of 3-year-old trees in 1-parent progeny tests shows strong correlation with crown width of mother tree. This holds true for both wide-crown and narrow-crown trees.

BISHOP, G. N., and NELSON, T. C.

1955. A winter key to the hickories of Georgia. Southeast. Forest Expt. Sta. Research Note 89.

Includes 9 species with names corresponding to the latest check list.

DORMAN, K. W.

1955. Short-time and long-time possibilities of selection in forest trees. Proc. Third South. Conf. on Forest Tree Improvement, pp. 31-35. New Orleans

Selection of improved tree types should be based on results of studies of inherent variation within each species. Many economically important plant varieties have been obtained by selection, but the process does not create new types--it merely isolates those occurring naturally.

DORMAN, K. W.

1955. Progress in tree improvement research at the Southeastern Forest Experiment Station. Proc. Lake States Forest Tree Improvement Conference, pp. 28-33. Lake States Forest Expt. Sta. Misc. Report No. 40. 108 pp.

DORMAN, K. W.

1955. Vegetative propagation problems in the South. Proc. Lake States Forest Tree Improvement Conference, pp. 56-57. Lake States Forest Expt. Sta. Misc. Report No. 40, 108 pp.

ECHOLS, R. M., and MERGEN, F.

1955. How to extract large wood samples from living trees. Jour. Forestry 53(2): 136.

Successful method was to bore two holes to pith, insert flat-sided plugs as saw guides, saw between holes, and then chisel out the sample.

HARGREAVES, L. A., Jr., and DORMAN, K.W.

1955. Georgia starts pine seed orchards. South. Lumberman 191 (2393): 189. Dec. 15.

Scions of superior phenotypes in loblolly and slash pine will be grafted on run-of-the-mill seedlings in establishing 500 acres of seed orchards.

HEPTING, G. H.

1955. Littleleaf. The Unit 58: 74-75.

Status of littleleaf and research on control through genetics and soil management. Forest management in littleleaf areas is discussed.

LOTTI, T.

1955. Yellow-poplar height growth affected by seed source. Tree Planters' Notes 22: 3.

At the end of the third growing season the mountain strain averaged 4.4 feet in height and that from the Coastal Plain 7.9 feet.

MERGEN, F.

1955. Air-layering of slash pines. Jour. Forestry 53(4): 265-270.

The feasibility of air-layering as a technique in asexual propagation of slash pine is demonstrated.

MERGEN, F.

1955. Anatomical study of slash pine graft unions. Quart. Jour. Fla. Acad. Sci. 17(4): 237-245.

The pith and phloem were active in forming a union of stock and scion which was usually complete in about 6 weeks.

MERGEN, F.

1955. Grafting slash pine in the field and in the greenhouse. Jour. Forestry 53(11): 836-842.

Summarizes experiments with cleft, veneer or side-slit, and bottle grafts in the greenhouse and field.

MERGEN, F.
1955. Inheritance of deformities in slash pine. South. Lumberman 190(2370): 30-32. Jan. 1.

Progeny after open pollination of a crooked slash pine were 76 percent crooked; those of the same tree crossed with a straight tree were 68 percent crooked; those of the straight tree used as a female parent tree in other crosses were 41 percent crooked.

MERGEN, F.
1955. Rooting and grafting of slash pine. Proc. Third South. Conf. on Forest Tree Improvement, pp. 88-94. New Orleans.

Describes successful techniques for rooting, grafting, and air-layering.

MERGEN, F.
1955. Vegetative propagation of slash pine. Southeast. Forest Expt. Sta. Paper 54, 63 pp.

Presents details of many experiments in asexual propagation of the species.

MERGEN, F., HOEKSTRA, P. E., and ECHOLS, R. M.
1955. Genetic control of oleoresin yield and viscosity in slash pine. Forest Science 1(1): 19-30.

Gum yield and viscosity were highly controlled genetically, while number and size of resin ducts were not.

MERGEN, F., ROSSOLL, H., and POMEROY, K. B.
1955. How to control the pollination of slash and longleaf pine. Southeast. Forest Expt. Sta. Paper 58, 14 pp.

Latest techniques are presented in true-to-life drawings.

OSTROM, C. E.
1955. The tree improvement research program of the Southeastern Forest Experiment Station. Proc. Third South. Conf. on Forest Tree Improvement, pp. 101-104. New Orleans.

Studies in variation and inheritance, project work in selective breeding, and many facilitating studies are being conducted concurrently at several Research Centers.

POMEROY, K. B.
1955. Selecting slash pine for greater yields of turpentine. Proc. Third South. Conf. on Forest Tree Improvement, pp. 47-49. New Orleans.

Gives evidence that gum-yielding ability is strongly inherited in slash pine and that it is possible to select and breed genetically superior trees.

POMEROY, K. B.

1955. Up-grading slash pine seed sources. Proc. Soc. Amer. Foresters (1954) pp. 74-75. Also, with title How we get good pine seed, Progressive Farmer 70(10): 34D.

Recommends selection of genetically superior trees and establishment of clonal seed orchards.

POMEROY, K. B., and MERGEN, F.

1955. Better slash pine seed. Forest Farmer 14(6): 11. Also, with title Better forests a reality, National Container Digest 8(4): 5, 1954.

An 86-acre seed producing area was created by removing undesirable phenotypes from a 20-year-old slash pine plantation.

ZAK, B.

1955. The grafting of shortleaf and other pine species. Southeast. Forest Expt. Sta. Paper 59, 13 pp.

Describes the use of cleft, bottle, side, veneer, and "soft tissue" grafts, both indoors and out. Factors affecting the success of grafting are discussed. Soft tissue grafts were especially successful, both intraspecific and interspecific, and are recommended wherever feasible.

ZAK, B.

1955. Inheritance of resistance to littleleaf in shortleaf pines. Southeast. Forest Expt. Sta. Research Note 88.

In growth and resistance to Phytophthora root rot, open-pollinated progeny from littleleaf trees were inferior to open-pollinated progeny from associated healthy trees.

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NANCIAL ASPECTS OF PRUNING PLANTED SLASH PINE

by

Frank A. Bennett

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

FINANCIAL ASPECTS OF PRUNING PLANTED SLASH PINE

by

Frank A. Bennett
Southeastern Forest Experiment Station
Cordele Research Center, Cordele, Ga.

The recent tremendous surge in the planting of southern pines will soon bring a corresponding surge of interest in the profitability of pruning. In anticipation of such interest, this paper presents some cost and return figures for pruning planted slash pine.

Since the idea of pruning is to produce the maximum proportion of clear lumber, the knotty core must be held to a small diameter. This in turn means that the tree should be pruned at an early age, and preferably in two phases. Results from a study 1/ at the George Walton Experimental Forest, Dooly County, Georgia, indicate that the first phase of pruning to a height of 8 feet should be accomplished when the trees are 15 feet tall (about 5 or 6 years of age), and the second phase to a height of 17 feet when the trees are about 33 feet tall (about 5 or 6 years later). By this method the knotty core can be held to a minimum diameter of 5 inches, and after each pruning the tree is left with a crown ratio of about 50 percent, a fact which insures that little or no loss in either diameter or height growth will be incurred.

What is the cost of this two-phase pruning? Records for the pruning of 21,400 trees on the Experimental Forest provide a good sample of cost data. Mr. H. E. Walton, owner of the forest and cooperator with the U. S. Forest Service in forest management research, paid for the work at the rate of 1 cent per tree for the first phase (pruning to 8 feet), and 4 cents per tree for the second phase (8 to 17 feet), making a total of 5 cents per tree. The entire cost for labor, supervision, travel, and marking of trees to be pruned is given in table 1.

The cost of marking the crop trees to be pruned in the second phase may appear too high, when compared with first-phase marking cost. Judging from experience, however, the second marking requires just about as long as the first because there are certain trees that must be eliminated. This results from forking and other conditions that develop after the first pruning, plus the occasional poor tree that was originally marked by error.

1/ Bennett, Frank A. A practical schedule for pruning planted slash pine. Southeastern Forest Expt. Sta. Research Note 53. 1954.

Table 1.--Two-phase pruning costs per tree for planted slash pine

Pruning level (Feet)	Labor	Marking	Strawboss and tallyman	Mileage	Total
	Cents	Cents	Cents	Cents	Cents
0 - 8	1.00	1.00	0.37	0.06	1/ 2.43
8 - 17	4.00	1.00	1.15	0.25	2/ 6.40
Sum	5.00	2.00	1.52	0.32	8.83

1/ Based on a total of 15,761 trees.
2/ Based on a total of 5,639 trees.

We now come to the question of clear volumes to be expected from the pruning operation. The clear volume of any log is equal, of course, to the total volume minus the knotty volume. Since the total volume of our pruned butt log can be scaled directly, the problem is to determine the volume of the knotty core, which we know to be 5 inches in diameter. Based on the International $\frac{1}{4}$-inch log rule, a 5-inch 16-foot log contains 10 board-feet. Added to this, however, must be a slab volume for the 5-inch core. According to Smith 2/ this slab volume can be calculated as 2.568 (diameter of the knotty core plus 0.75). Thus, to determine the clear volume of any pruned log, the following simple formula will suffice:

$$\text{Clear volume} = \text{total volume} - [\text{volume knotty core} + 2.568(\text{diameter knotty core} + 0.75)]$$

To go further and develop a table of clear volumes for butt logs of various sizes is simple. And by synthesizing a few points, the time involved and a net return can be established. For example, extensive records show that up to 20 years an annual diameter growth of 0.50 inch can be expected of the better trees with rather wide spacing on good sites. It seems reasonable to assume that we can expect 0.35 inch for another 10 years, and 0.30 inch thereafter through judicious management. Since records also show that at 16 years unpruned planted trees have an average form class of 68, it seems reasonable to expect an average form class of 76 at 20 years of age for pruned trees. Only the better trees were selected for pruning, and pruning will tend to increase the form class, since the greatest diameter growth is established as being at the base of the live crown. Also, as the tree ages, the form class will increase. Five percent is accepted by Mr. Walton as a fair rate of interest to place on the pruning investment, and

2/ Smith, J. H. G. The Economics of Pruning, Forestry Chronicle. 30: 2. June 1954.

present southern pine prices show an average differential of $30 to $35 per thousand board-feet between No. 1 common and clears. Table 2, based on these various factors, illustrates the clear volume, the cost, and the net return from pruned butt logs of different sizes. To point up the advisability of pruning early in order to hold the diameter of the knotty core as small as possible, data for different size knotty cores are included. The 5-inch knotty core represents an average tree pruned at the appropriate age and according to the recommended schedule. The 6-inch knotty core represents a tree pruned at a later age, and the 7-inch knotty core at a still later age.

In arriving at the total cost and net return, adjustments were made, according to Shaw and Staebler,[3/] for those pruned trees that are lost for one reason or another along the way. The figures are based on the premise that 150 trees per acre should be pruned in the first phase. It is then estimated that 10 percent of these trees will be eliminated or lost for the second phase. Of the remaining 135 trees that are pruned in the second phase it is estimated that 7.5 percent will be lost through mortality and other causes before the remaining ones are removed in intermediate and harvest cuts.

Considering these factors, pruning costs were adjusted as follows:

First phase:

Cost per tree	2.43 cents	
10 percent lost for 2nd phase, and thus final cost per tree is $\frac{2.43}{.90}$ =	2.70 cents	
2.70 cents compounded at 5 percent for 5 years, or until the second phase is accomplished, gives a complete first-phase cost per tree of		3.45 cents

Second phase:

Cost per tree	6.40 cents	
Adjusting for loss of 10 trees, or estimated 7.5 percent loss, final cost per tree is $\frac{6.40}{.925}$ =		6.92 cents
Total		10.37 cents

The figure of 10.37 is rounded to 10 cents in the table calculations and compounded at 5 percent for the appropriate number of years.

3/ Shaw, Elmer W. and Staebler, George R. An Analysis of Investments in Pruning. Journal of Forestry. 50: 11. 1952.

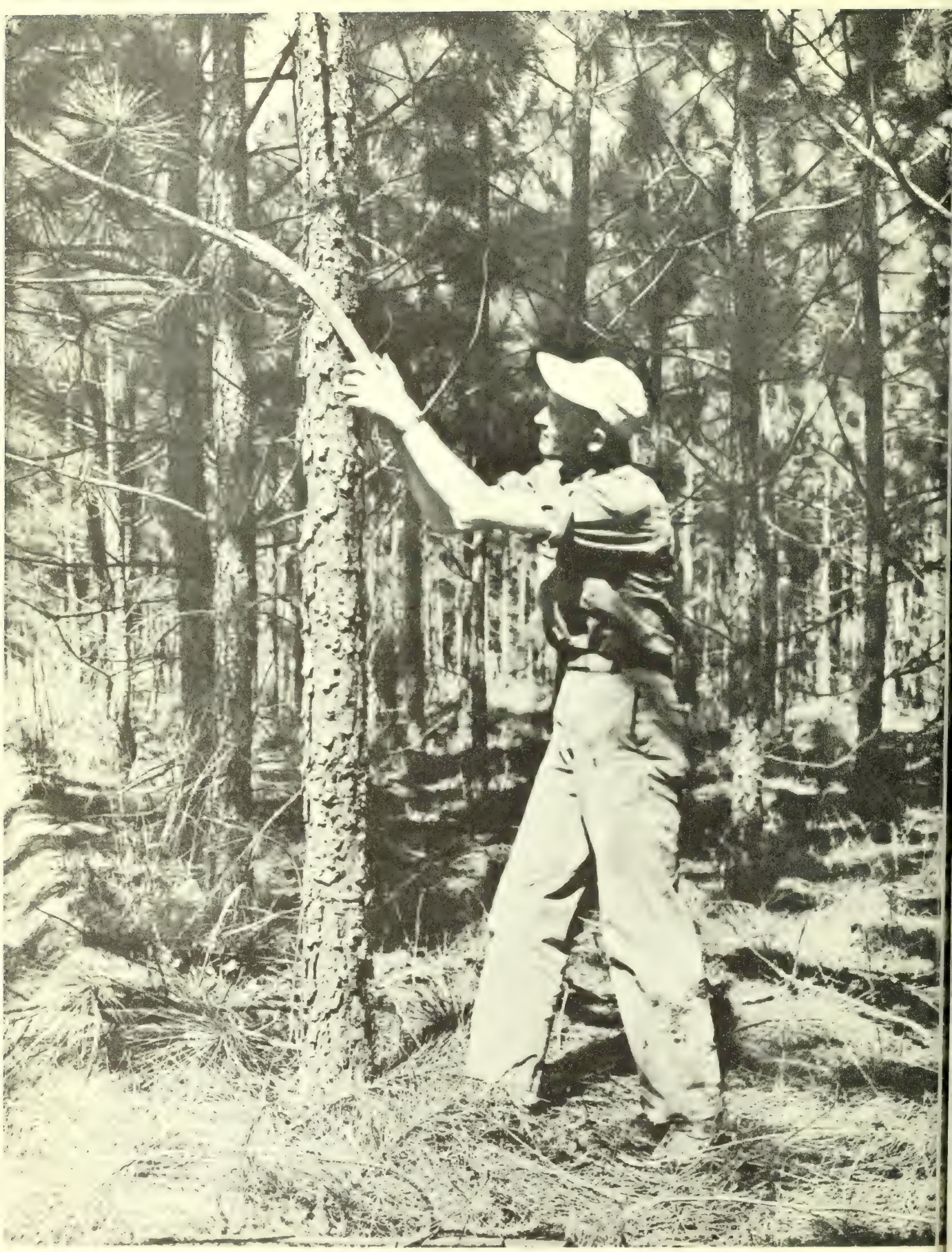

Figure 1.--First-phase pruning to 8-foot level at about 6 years of age.

Table 2.--Clear volume and net return comparisons for pruned butt logs of various sizes and knotty cores of different sizes

Scaling d.i.b. (Inches)	D.b.h.	Age	Form class	Clear shell thickness	Volume			Pruning cost at harvest	Net return per log 1/
					Total	Knotty	Clear		
	Inches	Years	Percent	Inches	- - -	Bd. ft.	- - -	Cents	Dollars
5-INCH KNOTTY CORE									
9	11.8	25	76	2.0	50	27	23	19.8	0.49
10	12.8	28	76	2.5	65	27	38	22.9	0.91
11	14.0	32	78	3.0	80	27	53	27.9	1.31
12	15.2	36	78	3.5	95	27	68	33.9	1.70
13	16.4	40	78	4.0	115	27	88	41.1	2.23
14	17.6	44	80	4.5	135	27	108	50.0	2.74
15	18.8	48	80	5.0	160	27	133	60.8	3.38
16	20.0	52	80	5.5	180	27	153	73.9	3.85
6-INCH KNOTTY CORE									
10	12.8	28	76	2.0	65	37	28	22.9	0.61
11	14.0	32	78	2.5	80	37	43	27.9	1.01
12	15.2	36	78	3.0	95	37	58	33.9	1.40
13	16.4	40	78	3.5	115	37	78	41.1	1.93
14	17.6	44	80	4.0	135	37	98	50.0	2.44
15	18.8	48	80	4.5	160	37	123	60.8	3.08
16	20.0	52	80	5.0	180	37	143	73.9	3.55
7-INCH KNOTTY CORE									
11	14.0	32	78	2.0	80	50	30	27.9	0.62
12	15.2	36	78	2.5	95	50	45	33.9	1.01
13	16.4	40	78	3.0	115	50	65	41.1	1.54
14	17.6	44	80	3.5	135	50	86	50.0	2.08
15	18.8	48	80	4.0	160	50	110	60.8	2.69
16	20.0	52	80	4.5	180	50	130	73.9	3.16

1/ Based on a premium of $30 per M bd. ft. for clears.

Figure 2.--Second-phase pruning at about 11 years of age.

The advantage of holding the diameter of the knotty core as low as possible is clearly shown in table 2. Not only is the volume of clear material increased, but clear material can be cut at younger ages and smaller sizes. This means that clear volume need not be restricted to the final crop trees, but can be produced in trees removed in intermediate cuts. Inspection of table 2 shows, for instance, that with a knotty core of 5 inches at 32 years of age the net return from pruning one butt log is $1.31, while with a 6-inch knotty core it is only $1.01, and with a 7-inch core only $0.62.

The interest rate of 5 percent may not be appropriate for any and all operations. The rate may vary between ownerships or between regions. For these reasons, table 3 presents earnings from pruning at various interest charges. It should be pointed out here that the net return from pruning does not increase indefinitely with age, as might be inferred from the tables. Eventually, say at 40 to 50 years, unpruned stands begin to produce some clear volume. Consequently, the proportion of the growth in clear volume attributable to pruning begins to diminish, while the compounded cost of pruning continues to rise.

Table 2 shows no saleable clear volume until 25 years of age, with all limbs having been removed at 11 years of age to a 5-inch knotty core. Inspection of 10-year-old plantations spaced 6 by 8 feet shows that no trees have shed the first whorl of branches, although the branches died some years ago. This indicates that the possibility of producing clear volume through natural pruning at early ages is remote. In order to induce natural pruning at a reasonable age, the density must be allowed to reach a point that shortens crown ratios to an extreme not commensurate with good management. Not only would diameter growth be reduced materially, but slash pine appears to reach a point beyond which it loses the ability to respond promptly to release. This has been observed on the experimental forest more than once.

In expanding the cost and return figures in table 2 to an acre basis, table 4 presents a projected 5-year cutting cycle for a plantation and outlines the returns from pruning the butt log on 125 crop trees.

On the basis of a 50-year rotation, the premium received for the clear lumber in the butt log, beyond the cost of pruning, averages $266.52 per acre. As granted earlier, a portion of the clear volume added in the last 10-15 years is probably not the result of pruning. We can concede, however, that no clear volume added after 30 years of age is attributable to pruning, and still show a net gain in lumber value of $94.27--assuming, that is, that all clear volume added before 30 years is the result of pruning.

Table 3.--Net return comparisons for pruned slash pine at various interest rates

Scaling d.i.b. (Inches)	D.b.h.	Age	Clear volume	Net return at-- 3%	4%	5%	6%	7%
	Inches	Years	Bd. ft.	Dollars				
5-INCH KNOTTY CORE								
9	11.8	25	23	0.54	0.52	0.49	0.46	0.43
10	12.8	28	38	0.97	0.95	0.91	0.87	0.82
11	14.0	32	53	1.40	1.36	1.31	1.25	1.18
12	15.2	36	68	1.82	1.77	1.70	1.61	1.50
13	16.4	40	88	2.40	2.33	2.23	2.10	1.93
14	17.6	44	108	2.98	2.88	2.74	2.56	2.31
15	18.8	48	133	3.70	3.56	3.38	3.13	2.77
16	20.0	52	153	4.26	4.09	3.85	3.50	2.99
6-INCH KNOTTY CORE								
10	12.8	28	28	0.67	0.65	0.61	0.57	0.52
11	14.0	32	43	1.10	1.06	1.01	0.95	0.88
12	15.2	36	58	1.53	1.47	1.40	1.31	1.20
13	16.4	40	78	2.10	2.03	1.93	1.80	1.63
14	17.6	44	98	2.68	2.58	2.44	2.26	2.01
15	18.8	48	123	3.37	3.26	3.08	2.83	2.47
16	20.0	52	143	3.95	3.79	3.55	3.20	2.69
7-INCH KNOTTY CORE								
11	14.0	32	30	0.71	0.67	0.62	0.56	0.49
12	15.2	36	45	1.14	1.08	1.01	0.92	0.81
13	16.4	40	65	1.71	1.64	1.54	1.41	1.24
14	17.6	44	86	2.28	2.22	2.08	1.90	1.65
15	18.8	48	110	2.98	2.87	2.69	2.44	2.08
16	20.0	52	130	3.56	3.40	3.16	2.81	2.30

Table 4.--A projected 5-year cutting cycle for a slash pine plantation, illustrating the return per acre from pruned trees

Age (Years)	D.b.h.	Trees	Basal area		Trees cut	Clear volume cut 2/	Premium from pruning	Cost of pruning	Net return from pruning 1/
			Before cutting	After cutting					
	Inches	Number	Square feet		Number	Board feet	Dollars		
25	11.8	125	94.92	83.60	15	345	10.35	2.97	7.38
30	13.5	110	109.34	84.49	25	925	27.75	6.32	21.43
35	15.0	85	104.31	85.90	15	1,050	31.50	4.83	26.67
40	16.5	70	103.94	86.12	12	1,068	32.04	4.93	27.11
45	17.7	58	99.10	82.02	10	1,090	32.70	5.25	27.45
50	19.2	48	96.51	--	48	6,288	188.64	32.16	156.48
Totals	--	--	--	--	--	10,766	$322.98	$56.46	$266.52

1/ On the basis of a 5-inch knotty core and a premium of $30 per M bd. ft. for clears.

2/ From butt logs only.

It has been stated that the owner cannot realize a benefit from pruning because buyers of either stumpage or logs will not recognize the presence of clear material and consequently will bid no more than for the average unpruned stand or log. Yet all buyers admit they bid considerably more for a stand with a good percentage of clears than for a stand with few or no clears. This being true, there appears little reason to doubt that an owner can realize a good profit from pruning planted slash pine if he markets his timber on a competitive basis and gives assurance to the bidders of a certain minimum volume of clear material.

Agriculture--Asheville

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Profits From Pruning Appalachian White Pine

by

Robert A. Campbell

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

PROFITS FROM PRUNING APPALACHIAN WHITE PINE

by
Robert A. Campbell, Forester
Southern Appalachian Research Center

INTRODUCTION

Although the acreage of white pine in the Southern Appalachians is relatively small compared with the area of other forest types, this species is important to the forest economy of the region because of the high unit value of the product and large potential returns per acre. Of the $3\frac{1}{2}$ million acres of white pine from Maryland southward, four-fifths were estimated to be immature or below sawtimber size, according to the unpublished "Report on White Pine Blister Rust Control for the Southern Appalachian Region," issued in 1951 by the Bureau of Entomology and Plant Quarantine, USDA. Thus, the possible returns from pruning young white pine stands are very large.

Studies made by Ball (2) indicate that the acreage of white pine is increasing in the region. A high proportion of these stands are now or soon will be of a size suitable for pruning. Furthermore, white pine is being planted at the rate of over 5 million seedlings per year (1). Assuming an average of one thousand seedlings per acre, this means another 5 thousand acres of white pine yearly, in addition to the areas seeding in naturally.

Of all eastern conifers white pine has the most persistent limbs, and is most in need of pruning if clear lumber is to be produced under management. But information on pruning white pine in the Appalachians is very fragmentary, and no previous analysis of its profitability is available.

This publication summarizes results of a 19-year test of healing time and growth rate of white pines after pruning, and analyzes the profitability of the pruning operation. Specific purposes of the study were:

(1) to determine average healing time for various size knots.

(2) to determine average diameter growth of pruned trees per decade.

(3) to incorporate the results of the above findings into a study of the profitability of pruning white pine in this region

LITERATURE REVIEW

Most of the past research on pruning eastern white pine has been done in New England, where white pine has been a mainstay of local industry since colonial times.

An early report by Cline and Fletcher (6) in 1928 covered the number and kind of trees to prune, height of pruning, tools to use, cost of pruning, and the expected profit. They found pruning yielded a profit of at least $15 per thousand board-feet. The next comprehensive study was made in the same general area by Hawley and Clapp (9). They recommended specific pruning practices, and gave detailed costs for these. Mollenhauer (13), in 1938, conducted a very complete time-cost study of pruning planted white pine in Maryland. He tested several methods and more than 20 tools, and gave detailed time results and comparisons. In 1940, Jensen and others (12) analyzed the increase in white pine timber values due to pruning. Barrett and Downs (3) reported in 1943 on the growth response of white pine to green pruning in the Southern Appalachians. Their study was based on the same trees used in this report.

Since 1950 most of the white pine pruning literature has to do with results in the West on Pinus monticola (Huey, 11). A comprehensive recent publication by J. H. G. Smith (16) deals with profits from pruning Douglas-fir and ponderosa pine, but is generally applicable to white pine and other conifers. He presented a general method for determining the diameter growth at breast height that would result in various clear-shell thicknesses in pruned trees. His method was used in the present study.

Pruning cost tends to be directly proportional to limb size (6) and to tree diameter (4, 8, 15, 16). Including an additional half log above the butt log nearly doubled the pruning cost in longleaf pine (8). In slash pine pruning, the upper 9 feet cost more than 3 times as much as pruning the first 8 feet (5). Some pruning rates reported earlier were 95 and 85 linear feet per hour for New England white pine (6, 9), and 144 feet for planted white pine in Maryland pruned by the Tarzan, or climbing, method (13).

Stand density is not an important factor in pruning cost, in planted white pine (13), or in longleaf pine (8), but it is very important to pruning profits through its effect on growth rate.

White pines should be pruned when potential crop trees can be picked and pruned safely in one or two operations without removing over one-third of the live crown. Pruning should be done when the trees reach 4 to 5 inches in diameter as recommended by Barrett and Downs (3), in their earlier report of this study. Helmers (10) came to the same conclusion regarding crown lengths in pruning western white pine. Dahms (7) recommended the same limits of pruning; that is, not over one-third the live crown for ponderosa pine.

THE STUDY

The current study, conducted on the Toccoa Experimental Forest in Union County, North Georgia, was a follow-up of the white pine pruning study begun by Barrett and Renshaw in 1936 and reported by Barrett and Downs in 1943 (3).

The study area is a 5-acre natural stand of white pine located on a south-facing slope along Mulky Creek. The soil is a well drained sandy loam,

and the area can be classed as a good site in general, despite some small local variations. Height measurements of the 37-year-old trees indicate a site index of approximately 100 feet at age 50.

At the time of pruning, early in May of 1936, the stand was about 20 years old. All the pruned trees were liberated from competing trees at that time, but many of the smaller trees have become suppressed since pruning. Proper thinnings would have prevented this. The sectioned trees averaged form class 80.

Procedure

In the original study, several different pruning tools were used, including axes, saws, and the Rich mace axe. A hand saw was used in pruning all trees to a height of 8 feet. Other tools were used on trees pruned from 8 to 14 feet, and saws again above 14 feet to a variable upper limit which did not exceed 22 feet. Because of the superior job done with a saw, only trees so pruned were included in the current study. Therefore, sample trees were selected from the trees pruned to 8 feet and those over 14 feet; 24 of these trees (approximately half) were chosen for this study. The other half were left for a subsequent grade-yield study at the time of harvest--some 20 years hence.

Total height and diameter at breast height were determined for each tree before felling. After felling in December 1954, the trees were cross-sectioned at the stump, middle, and top of the pruned log. Healing time for knots of various diameters at the stump, middle, and top of the log was observed on the cross sections cut at these intervals with a power saw. The sections were smoothed on a planer to improve the ease and accuracy of measurements of growth and healing time. Longitudinal sections were also made, as shown in figure 1, to check on healing time and alignment of grain of the pruned log.

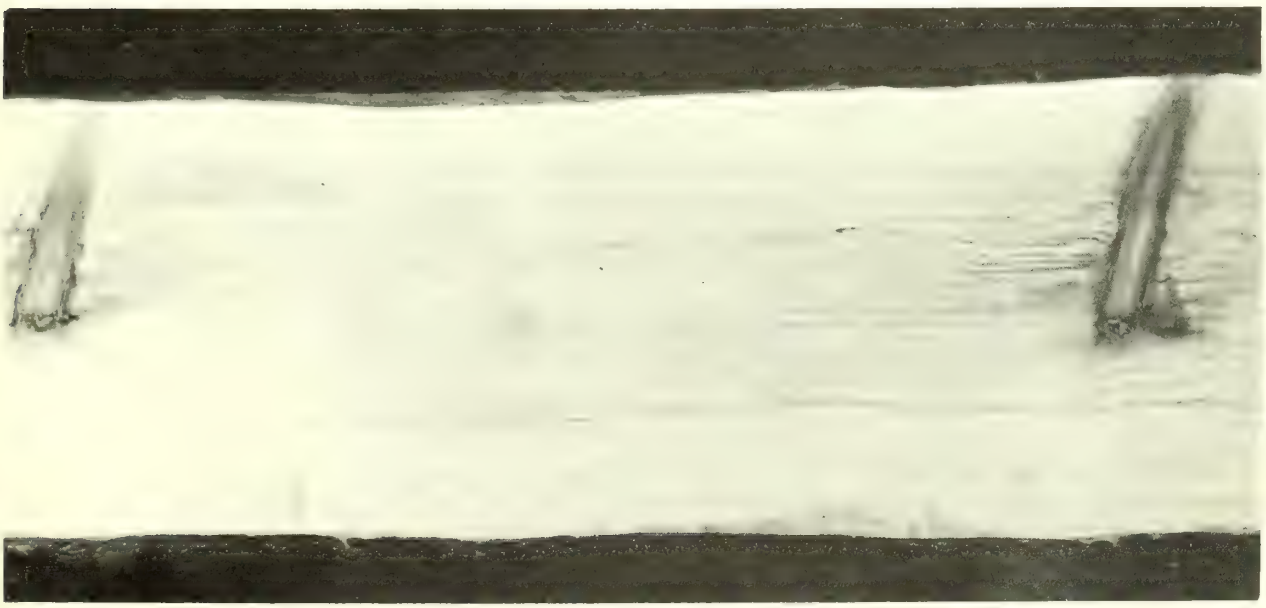

Figure 1.--Quartered section of pruned white pine log 19 years after pruning, showing grain alignment and about 3 inches of clear shell.

Regression analyses were made of the following relationships: (1) healing time compared with knot size, and (2) d.b.h. at time of pruning compared with d.b.h. 8, 11, and 19 years later.

Results

Healing time is significantly related to knot size and to growth rate. The nature of this relationship is shown in figure 2. In this study the average $\frac{1}{2}$-inch knot healed over completely in 3 years, but the average 1-inch knot required nearly 5 years.

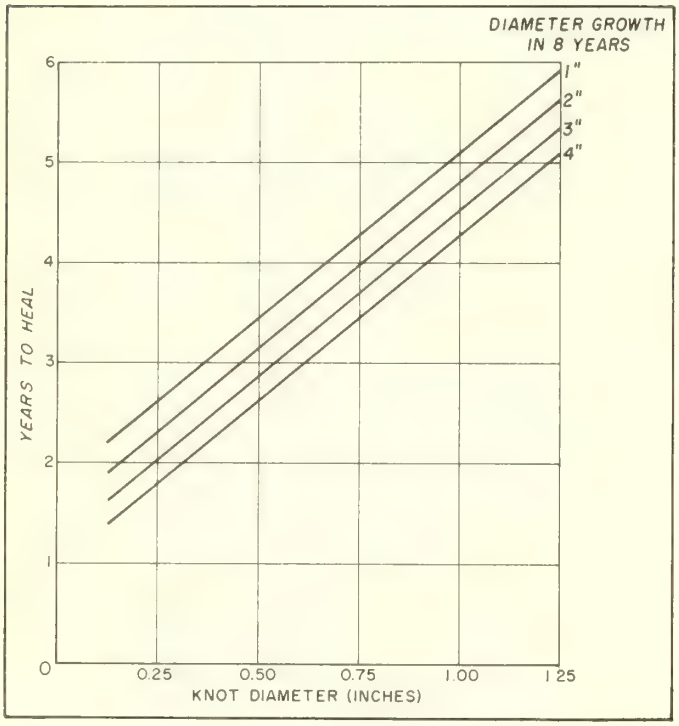

Figure 2.--Relation of healing time in years to knot diameter at time of pruning and to subsequent 8-year diameter growth (based on regression analysis of 52 knots).

Diameter growth in relation to time since pruning is illustrated in figure 3. A good growth rate is imperative in showing a pruning profit. As shown in figure 3, the larger trees pruned in 1936 grew very rapidly in the ensuing 19 years (more than 8 inches in diameter), even though they were thinned only when pruned in 1936. The differences in growth rate shown in figure 3 emphasize the need for picking the most likely crop trees for pruning. Crop trees cannot be selected properly until trees reach 4 or 5 inches in diameter (3). Periodic thinnings are also needed in order to maintain a good growth rate on the pruned trees.

PRUNING COSTS

Pruning costs, in general, are directly related to the number of trees pruned per acre and the size of the tree when pruned. Other related factors to be considered are pruning tools and methods, season of year, stand density, percent of live crown removed, and number and size of limbs. In the Toccoa

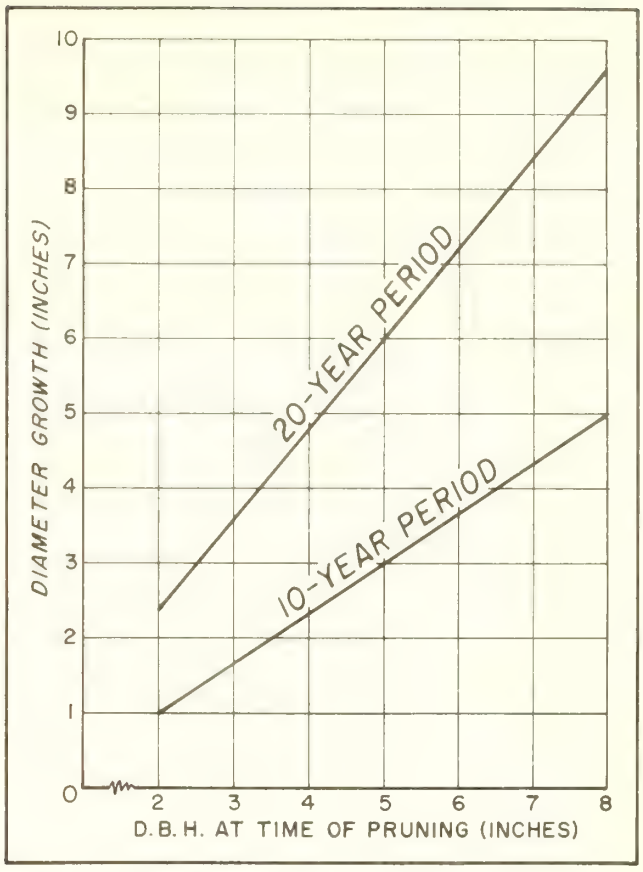

Figure 3.--Diameter growth of pruned white pine in relation to diameter at time of pruning (based on regression of 24 pruned trees).

study, pruning time was not recorded in detail, but it was found that an average of 10 trees were pruned per man-hour. At an average height of 10 feet this would amount to 100 linear feet per hour, which compares closely with the average of 95 linear feet given by Cline and Fletcher (6).

Paul's studies (14) indicate that pruning time and costs for white pine are comparable to those for shortleaf pine, since knot size, number and limb retention time are similar. Because of these similarities and in the absence of local white pine cost data it was decided to use Bent Creek 1/ pruning costs for shortleaf pine, namely 7 to 11 cents per tree, depending on size and limbiness. These costs are for labor only at 75 cents per hour. When these costs are converted to 85-cent wages plus 25 cents for travel and overhead as above, the total cost per tree is 10 to 16 cents for trees from 4 to 7 inches in diameter, or $10 to $16 per acre for 100 pruned trees.

PRUNING PROFITS

Profits from pruning vary according to (1) cost of pruning, (2) value of clear vs. knotty lumber, and (3) thickness of clear shell or proportion of clear lumber and the time required to grow it.

An important consideration in the profitability of pruned white pine is the high value of knotty white pine for paneling. Not all knotty pine, however,

1/ Bent Creek is the experimental forest of the Southern Appalachian Research Center, located near Asheville, N. C.

has a high value for this purpose; the lower limbs, which may persist for a long time after they die, result in loose, black knots unfit for paneling. The best paneling in unpruned stands comes from the upper logs containing solid knots from green limbs. To make a profit from pruning, preliminary cost calculations indicate the need for a spread in value between clear and knotty lumber of at least 50 percent in favor of the clear, according to Cline (6) and Jensen (12). Hawley (9) and Smith (16) assigned twice as much value to clear lumber as to the highest knotty grade.

In the preliminary calculations leading up to this report, clear lumber values from 50 to 100 percent over those for knotty lumber were used. The purpose of the sliding scale was to allow for the premium given for wider and thicker boards which can be cut only from the larger logs and trees.

Tables 1 and 2 show the costs and expected returns from pruning trees of various sizes. Growth rates for past and future periods shown in table 1 are based on the study average of 3 inches diameter growth at breast height every 10 years. This is a conservative rate for well managed stands on good sites. Extra diameter growth to allow for knot-healing time, for bark thickness, and for taper have been included in the diameter figures of line 2, table 1. The data have been computed for pruning trees 4, 5, and 6 inches in diameter, and for an average harvest age of 70 years. Actually, the pruned trees would be removed in different types of cuttings at different times in a managed stand. Costs have been compounded at a 4-percent rate of interest. Values shown per thousand board-feet are for pruned butt logs only, and are harvest values less compounded pruning costs. Stumpage values per thousand board-feet would probably be from one-fourth to one-third of the lumber value shown in table 2. Hence the landowner or timber grower cannot expect to recover more than a third to a half of the profits indicated in table 2 unless he logs, mills, and sells the lumber as well as raises it.

As shown in table 2, harvest-time profits per tree range from $11.38 to $13.27, depending on tree size at the time of pruning. Profits range from $57 to $63 per thousand board-feet for pruned butt logs at time of harvest, and per-acre profits average close to $700. Profits per acre are not greatly affected by pruned tree size in this study when growth rate and shell thickness are kept constant.

A 6-inch clear shell was selected as the basis for tables 1 and 2 because this clear shell thickness gives optimum annual return. Profits from a 5-inch clear shell would be less, and from a 7-inch shell more. These profits are shown as percentages in the following comparison:

Pruning diameter	5-inch clear shell	6-inch clear shell	7-inch clear shell
	(Percent)	(Percent)	(Percent)
4 in.	60	100	110
5 in.	55	100	120
6 in.	50	100	130

Table 1.--Growth and volume of white pine pruned at 4-, 5-, and 6-inch diameters and held for 53, 54, and 55 years, respectively--time needed to grow a 6-inch clear shell

Pruned tree d.b.h. (inches)	D.b.h. growth o.b. needed for 6-inch clear shell [1]	Total d.b.h. at time of harvest	Average 10-year d.b.h. growth assigned	Butt log d.i.b. at harvest [2]	Butt log volume, clear [3]	Butt log volume, knotty
	Inches				Board feet	
4	16.0	20.0	3.0	16.0	165	15
5	16.3	21.3	3.0	17.0	180	25
6	16.5	22.5	3.0	18.0	200	30

1/ The 6-inch clear shell is measured at top of butt log. To produce this, the diameter at breast height must be more than double clear-shell thickness. Explanations regarding this allowance for taper and slab are given by Smith (16).

2/ Using i.b. form class of .80 for total d.b.h. at time of harvest.

3/ From figure 2, Smith (16).

Table 2.--Pruning costs and harvest values for white pine pruned at 4-, 5-, and 6-inch diameters and held for 53, 54, and 55 years, respectively--time needed to grow 6-inch clear shell
(In dollars)

Pruned tree d.b.h. (inches)	Cost			Value		Profit at harvest		
	Initial pruning	Pruning plus 20% mortality [1]	Pruning and mortality compounded at 4%	Pruned log [2]	Unpruned logs [2] [3]	Per tree	Per M bd. ft. [4]	Per Acre [5]
4	.10	.12	1.00	30.38	18.00	11.38	63.00	683.00
5	.13	.16	1.33	34.00	20.50	12.17	59.40	670.00
6	.16	.20	1.73	38.00	23.00	13.27	57.00	664.00

1/ Initial cost of pruning divided by 0.80.

2/ Values based on prices of $100 per M bd. ft. for knotty lumber and $175 for clear lumber.

3/ Assuming no clear lumber.

4/ Based on 5.5, 5.0, and 4.3 pruned butt logs, respectively, per M bd. ft.

5/ Harvesting 60, 55, and 50 trees, respectively, per acre.

CONCLUSIONS

The pruning of white pine promises to be a very worthwhile investment in the Southern Appalachians if confined to the better sites, if done early and properly, and if followed by light but frequent thinnings.

Pruning should be done only on the better sites, where the fast growth rate will offset the compounding of costs. Trees should be pruned when they are from 4 to 6 inches in diameter. Not over one-third the live crown should be removed in any operation.

Systematic thinnings starting at age 20 or at the time of the first pruning should be repeated every 5 years to age 40 and every 10 years thereafter to keep the growth rate of the pruned trees up to maximum and to prevent loss through mortality. Such a program should result in a profit of $700 or more per acre over and above the cost of pruning and thinning.

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Growth of Slash Pine Plantations on the George Walton Experimental Forest

by

Frank A. Bennett

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
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U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

GROWTH OF SLASH PINE PLANTATIONS ON THE GEORGE WALTON EXPERIMENTAL FOREST

by
Frank A. Bennett

INTRODUCTION

According to records of the Georgia Forestry Commission, about 625,000 acres have been planted to trees in Georgia since 1929. Of this total more than 75 percent has been planted to slash pine (Pinus elliottii Engelm.). Despite this great amount of planting, very few reports dealing with the development of slash pine plantations in Georgia are available. This paper is a report on the growth and yield of 21 slash pine plantations on the George Walton Experimental Forest, Dooly County, Georgia. It shows what may be expected of planted slash pine on upland coastal plain soils having a site index of 70 to 80 feet for natural stands.

Holt E. Walton of Cordele, Georgia, began acquiring marginal and submarginal farmlands in Dooly County in the mid-thirties, primarly for the purpose of gaining additional timber for his naval stores operation. After one or two unprofitable attempts at row-cropping the fields, he decided to plant them to slash pine. Twenty years later this program is still under way and more than 1200 acres of these fields have been planted.

The U. S. Forest Service has leased rent-free for 50 years 4200 acres of these lands for research purposes. Included in the area are 600 acres of Mr. Walton's plantings. Figure 1 outlines the forest and its plantations.

With one exception, all planting stock came from Georgia State nurseries. One shipment of seedlings came from Louisiana, but there is strong suspicion the seed were collected in north Florida and south Georgia. All planting was done with the planting bar. No site preparation was employed but most of the fields in the early years were cross-scored with a plow to indicate the desired spacing. In later years scoring has been in one direction only.

The spacing employed has varied from year to year. Emphasis at first was on naval stores and consequently all the older plantings are widely spaced--as few as 150 trees per acre. As pulp mills moved south and the market for pulpwood expanded, Mr. Walton reasoned that the wide spacings were not fully utilizing the growing space in the early years, and subsequent spacings were somewhat closer. The 1946 planting, for instance, was 6x8 feet, or 907 trees per acre. Most of the plantations of wider spacing are now of merchantable size and are the basis for this report. Plantings made since 1946 are not included.

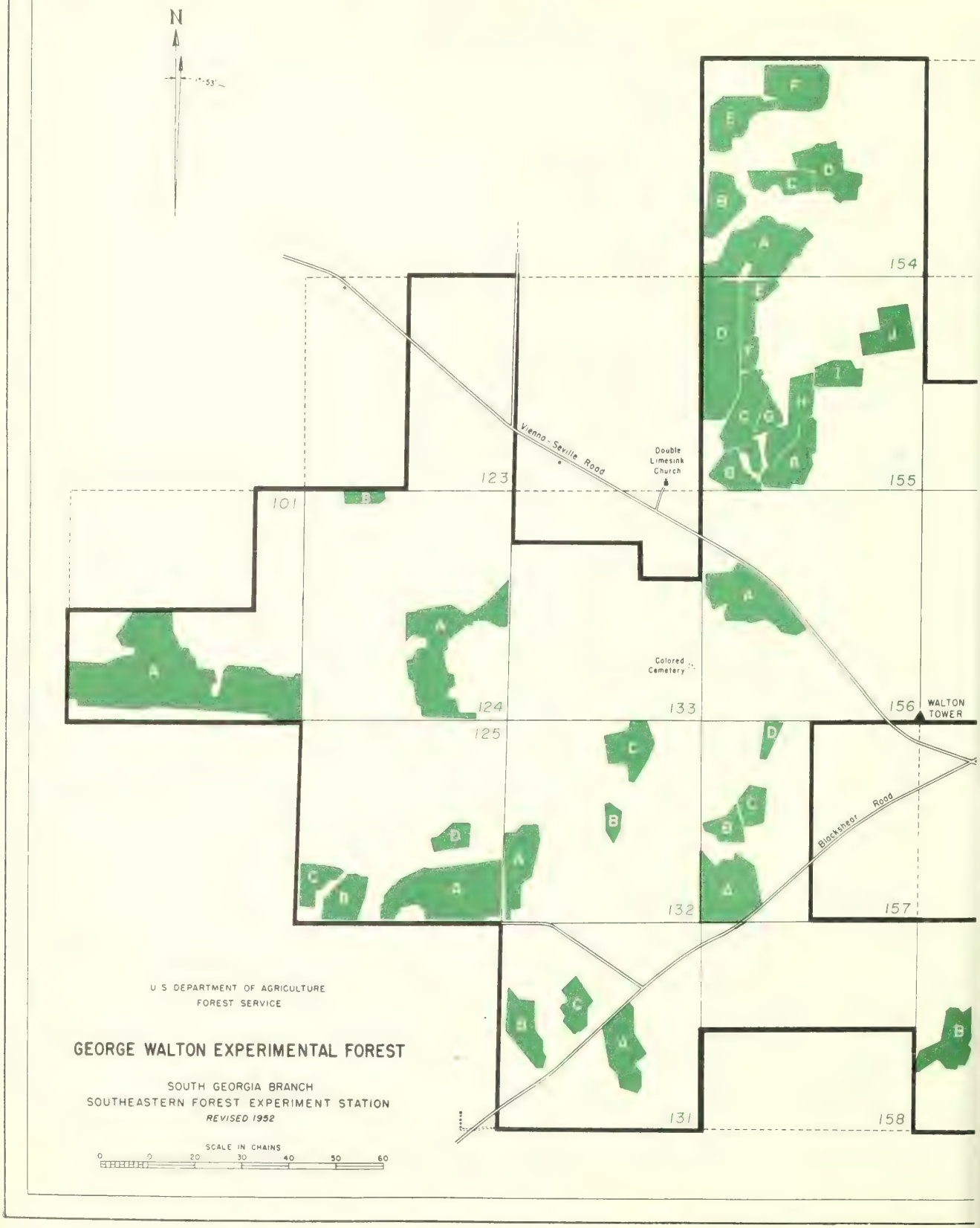
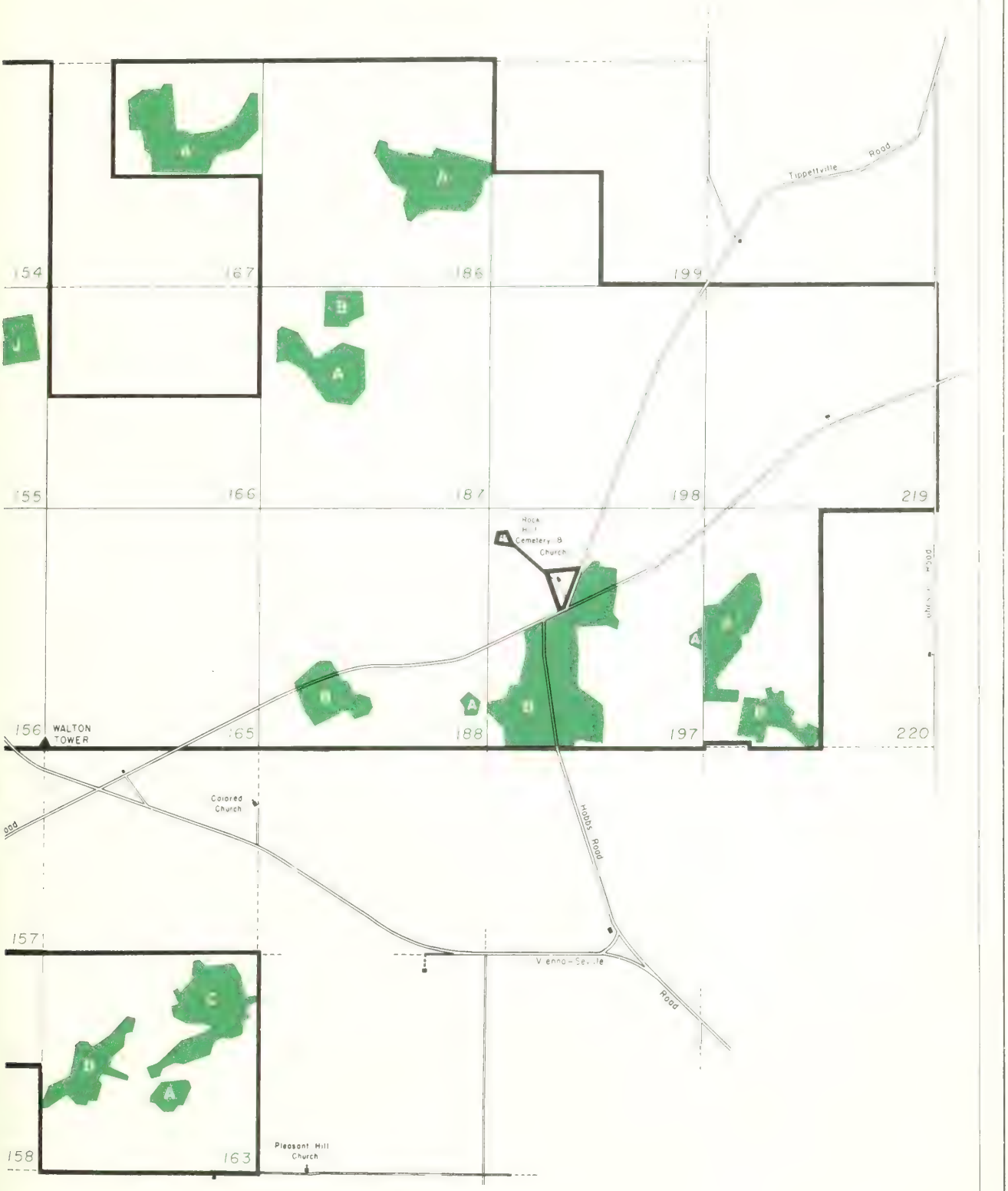


Figure 1.--Map of the George Walton Experimental Forest near Cordele, Georgia, showing location of the slash pine plantations.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Tippettville Road
Rock Hill Cemetery & Church
Colored Church
Hobbs Road
Venno-Seville Road
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158
163
Pleasant Hill Church

Although Walton made a strong effort to protect his holdings from wildfire, he was in a county without organized fire protection, and several of the plantations included in this report were severely burned once or more. Most of these burns occurred during the war years while Walton was in the armed forces and labor was scarce. Since the organization of the experimental forest, only 6 plantations out of the 47 shown on the map have burned; two of these were partial burns. Early in 1954, Dooly County organized a fire protection unit under state supervision and has aided greatly in protecting the experimental area.

SOILS AND CLIMATE

The Walton plantings are on soils typical of the middle coastal plain. For the most part they are loamy sands over a friable sandy clay subsoil. Drainage on most areas is good to excessive, with some minor areas having poor drainage. Better than 98 percent of the acreage in these plantations is represented in four soil series. Table 1 lists for the experimental forest the various soil series, the percentage of plantation acreage in each, and the site index for natural slash pine stands on each series. The site indexes ranged from 69 to 80 feet, averaging about 75 feet. Most of the stands from which these site indexes were derived originated in old fields. Thus, the growing conditions of the natural stands are quite similar to those for plantations growing on the same series. A detailed description of the soils is given in the appendix.

Table 1.--Summary of growth and survival by soil type and spacing for slash pine plantations on the George Walton Experimental Forest

Soil type	Site index 1/	Average spacing	Plantations	Area		Survival	Annual yield
	Feet	Feet	Number	Acres	Percent	Percent	Cords
Gilead loamy sand	80	15x16	9	219	63.2	78	1.22
Lakeland loamy sand	76	15x15	4	69	19.9	80	1.31
Cuthbert sandy loam	70	12x12	5	31	8.9	72	1.19
Susquehanna loamy sand	69	15x15	2	23	6.6	69	1.01
Mayhew sandy loam	(2/)	15x15	1	5	1.4	64	0.91

1/ Site index in this table refers to the height dominant and codominant slash pine have attained in natural stands at 50 years of age on a specific soil type on the George Walton Experimental Forest.

2/ Site index not available.

Rainfall on the experimental forest has averaged 48.26 inches annually for the past 7 years. The record by months and years is presented in table 2. There is wide variation in both the monthly and the annual precipitation. By months, it ranged from a minimum of 0.24 inch in October 1951 to a maximum of 10.50 inches in December 1953. By years, precipitation ranged from a low of 26.84 inches in 1954 to a high of 62.89 in 1953. The driest months are October and November. Rain is ordinarily well distributed among the remaining months.

Table 2.--Yearly and monthly rainfall from 1948 through 1954 on the George Walton Experimental Forest

Month	1948	1949	1950	1951	1952	1953	1954	Mean
	- - - - - - - - - - - - - - - - Inches - - - - - - - - - - - - - - - -							
January	5.34	2.74	1.68	0.93	2.29	4.43	0.98	2.63
February	4.25	5.52	2.16	1.18	6.57	6.01	1.19	3.84
March	8.36	3.23	5.78	5.46	7.87	4.31	2.85	5.55
April	5.22	4.15	1.73	2.76	2.94	5.09	1.38	3.32
May	2.88	2.90	7.56	1.42	4.69	5.20	4.22	4.12
June	2.69	7.14	3.89	3.58	3.18	3.81	1.36	3.66
July	8.08	9.20	4.79	9.43	0.73	6.42	3.86	6.07
August	3.92	8.08	1.98	3.74	5.33	4.29	3.20	4.36
September	2.08	2.60	4.39	5.87	7.51	10.12	1.37	4.85
October	6.65	1.87	4.35	0.24	0.86	1.48	1.37	2.40
November	5.72	0.65	0.95	4.28	1.47	1.23	2.71	2.43
December	6.66	0.84	5.92	4.55	5.28	10.50	2.35	5.16
Totals	61.85	48.92	45.18	43.44	48.72	62.89	26.84	
Mean	5.15	4.08	3.76	3.62	4.06	5.24	2.23	
						Yearly Mean		48.26
						Monthly Mean		4.02

In general, the climate is mild with a long growing season. The United States Weather Bureau reports the following dates for killing frosts for Dooly County, Georgia, and vicinity:

Average date of first killing frost	November 10
Average date of last killing frost	March 20
Length of growing season	235 days
Record early date of killing frost	October 11
Record late date of killing frost	April 26

GROWTH AND DEVELOPMENT

Detailed data on growth and development of the various plantations are recorded in table 8 in the appendix. No attempt at a formal analysis has been made because of the difficulty of reconciling the many influences affecting growth of the trees. Histories are given as completely as possible. All averages are based on 100-percent inventories, with the exception of height data, which are based on a random 10-percent sample.

At 11 years of age and over, survival ranged from 42 to 88 percent. The average was 74 percent. The low of 42 percent occurred in a plantation that was severely burned in May of its ninth growing season. Heavy mortality occurred at that time.

An interesting point is the survival of all plantations by soil series classes. This is shown in table 1 (the plantation with a 42-percent survival is not included). Survival figures are arranged in almost the same order as the site indexes of the various soils, and for each soil survival is almost the same figure as the site index.

Annual yields per acre at 11 years of age and over (table 8) ranged from 0.77 to 1.46 cords. The low yield occurred in a 16x17-foot spacing with a survival of 65 percent. This plantation was burned several times. The high yield of 1.46 cords occurred in two plantations--one spaced 11x11 and one spaced 17x17 feet. As far as we know,neither plantation ever burned. As expected, the yields of these plantations tend to parallel the productivity of the soil types, as indicated by their site index for natural stands of slash pine (table 1).

Table 3 gives the annual cordwood and basal area growth for the various spacings. There appears to be no real pattern of growth as related to spacing. Factors other than spacing have greatly influenced growth, and the data are not adequate for a regression analysis which might sort out the influence of each factor.

As table 8 shows, the 8x8 spacing suffered severe burns and numerous wildlings helped maintain the per-acre yield despite very poor survival. The 10x10, 11x11, and 17x17 spacings were never burned, have good survival, and have comparable yields. Two-thirds of the 15x15 and 16x16 spacings, on the other hand, suffered one or more severe burns and are below the other three spacings in average yields. As illustrated in table 8, when history and site are

Table 3.--Survival and growth in basal area and cordwood volume for slash pine planted at various spacings. Includes only plantations over 10 years of age

Spacing (feet)	Survival	Annual growth per acre	
		Volume	Basal area
	Percent	Cords	Square feet
8x8	42	0.95	4.28
10x10	72	1.34	5.65
11x11	84	1.46	5.72
15x15 1/	77	1.20	4.10
16x16 2/	78	1.10	3.77
17x17	(3/)	1.46	5.14

1/ Includes 15x16 spacings.
2/ Includes 16x17 spacings.
3/ No figure available, but survival is good.

Figure 2.--A plantation compartment clearcut at 19 years of age. This study contains 16 compartments designed to contrast returns from four rotations--19, 25, 35, and 50 years. The above compartment yielded 26.3 cords per acre mill scale, or an average of 1.38 cords per acre per year. The trees in the background are a portion of the same plantation.

similar the difference in growth between spacings is not pronounced. Figure 2 shows a plantation compartment with a 15x15 spacing, which was clear cut at 19 years of age. The annual yield, as scaled at the pulp mill yard, was 1.4 cords per acre.

Averaging all ages and spacings, basal area growth has been 3.90 square feet per acre per year. At age 11 and over, the average has been 4.78 square feet. The most rapid growth was 7.54 square feet in an 8-year-old plantation with a 6x8 spacing. The total at this age for this plantation was 60.33 square feet per acre, while the average diameter was 4.0 inches. Based on the present survival figure of 71 percent, total basal area per acre will be about 126 square feet when the average d.b.h. is 6 inches. Although this figure is well beyond the generally accepted point for release, it is obvious a thinning for pulpwood could not be accomplished earlier. Even a cut when the average diameter is 6 inches will present a problem, since analysis of eight plantations with an average diameter of 6.1 inches revealed that 16 percent of the trees were under the minimum merchantable size of 5 inches. Thus, if mechanical or alternate-row thinning is employed, one-sixth of the trees cut will be below 4.6 inches d.b.h. If a selective type of thinning is undertaken, the cut will have to be concentrated in the larger and thriftier stock.

If thinning is delayed until the average diameter is 6.5 inches--which would mean a basal area per acre of 148 square feet--we will still have to cope with the problem of undersize trees. In the wider spacings the first thinning presents no such problem, as figure 3 illustrates.

Figure 3.--Thinning a 19-year-old plantation compartment. Approximately one-fourth of the basal area and one-fourth of the volume was removed.

Annual diameter growth ranges from 0.40 to 0.73 inch for all ages and spacings. The average is 0.53 inch. Figure 4 shows sizes at various ages. Reference to table 8 will show that the closer spacings are not well represented in the older age classes, but that the wider spacings are well represented in the younger ages. As expected, diameter growth bears a direct relationship to spacing--the wider the spacing the greater the diameter growth (fig. 5). In relating diameter growth to spacing, the reader should remember that fire history favors the 10x10 and 11x11 spacings, since there is no record of these plantings ever having burned. On the other hand, a part of the plantings in each of the other three spacings have burned over one or more times.

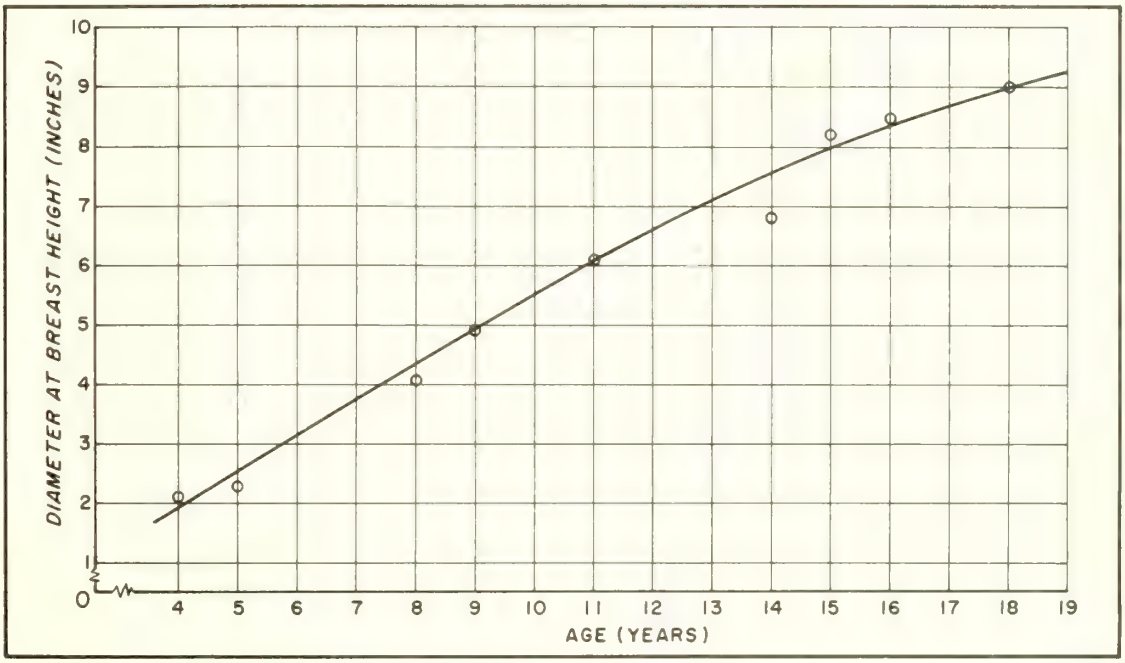

Figure 4.--Diameter of planted slash pine related to age for all soils and spacings.

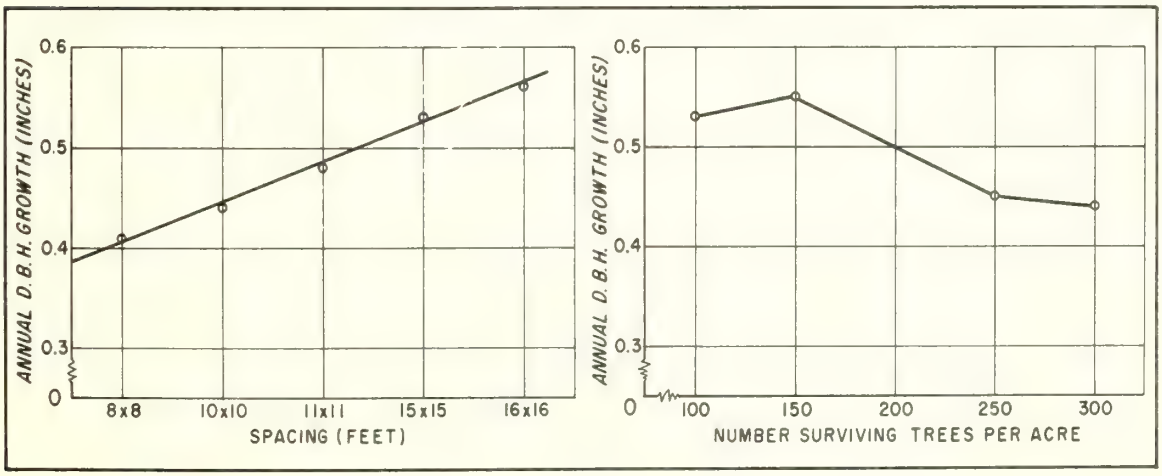

Figure 5.--Annual d.b.h. growth of planted slash pine in relation to spacing and number of surviving trees per acre at age 14 and over.

The distribution by diameter classes for the various spacings is a point of interest. The curves of figure 6 show that this distribution has a characteristic bell shape. Curves for the wider spacings, however, have much longer tails than do the closer ones. This is to be expected since the average diameter is considerably larger in the wide spacings. Figure 7 illustrates the unusual diameter growth made by a planted slash pine in a 15x15 spacing.

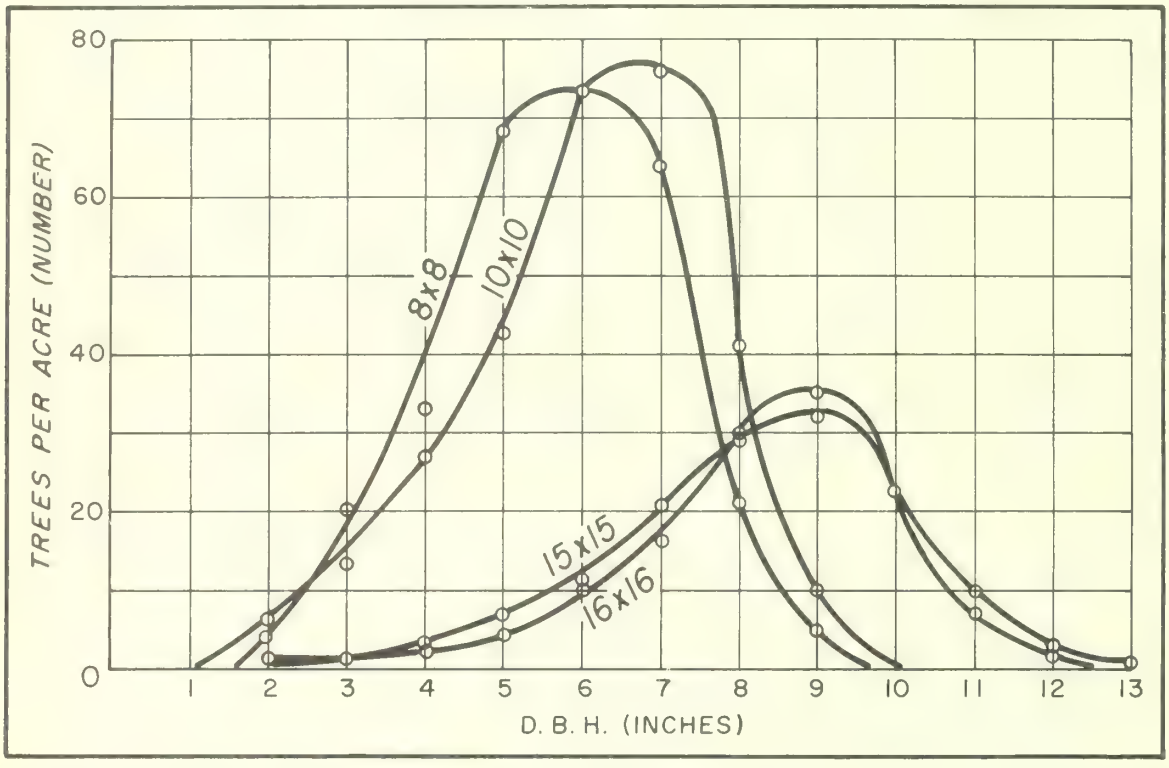

Figure 6.--Frequency distribution of diameters of planted slash pine for various spacings at age 14 and over. Each curve represents several plantations.

Figure 7.--Holt E. Walton, owner of the George Walton Experimental Forest and cooperator with the U. S. Forest Service in forest management research, calipering a 12-inch tree he planted 13 years before.

Height growth has averaged 2.85 feet annually. The range is from a low of 2.00 feet to a high of 3.87 feet. There seems to be no relation between spacing and height growth; table 4 illustrates this along with the relation to site index. It is interesting to note that the lowest average height growth of planted trees occurred on the soil with the lowest site index for natural stands, reflecting the reliability of these soil-type site indexes. Comparative photographs in figure 8 illustrate the rapid growth of field-planted slash pine.

Table 4.--Mean annual height growth of planted slash pine at 14 years of age and over for various spacings and by site index

Spacing (feet)	Plantations	Average soil site index [1/]	Mean annual height growth
	Number	Feet	Feet
8x8	1	80	2.9
10x10	2	77	3.0
11x11	1	70	2.6
15x15	6	78	3.0
16x16	3	78	3.0
17x17	1	78	3.3

1/ Average site index for natural slash pine associated with the soils on which each spacing occurs.

Figure 8.--Repeat photographs illustrating the rapid growth of planted slash pine. Dates of photos are: (left) October 28, 1949; (right) December 12, 1952. The trees were planted during the 1942-1943 planting season and are spaced 12x12 feet. At 11 years of age the plantation had an average of 15.64 cords per acre, which is an average yield of 1.42 cords per acre per year.

SAWTIMBER VOLUMES

In general board-foot production in these young plantations varies with spacing. The closer spacings produce little sawtimber volume by age 15 in comparison with the wider ones. Although the narrow spacings are not represented in the sawtimber age classes except by one small planting, it is apparent they would not measure up to the wider spacings in board-foot production, because the medium spacings fall far short in this respect. Sawtimber volumes for the various spacings appear in table 5.

The 8x8 spacing shows an average of 467 board-feet per acre at 14 years of age, but only 55 feet of this are in planted trees, distributed among only two sawtimber trees per acre. The other 412 board-feet occur in wildlings, as the large average diameter indicates.

Table 5.--Survival, average d.b.h., and board-foot volume production for slash pine plantations of various ages and spacings

Plantation number	Spacing	Age	Survival	Sawtimber stand per acre				Average size of sawtimber trees	
				Trees	Volume			D.b.h.	Volume
					Planted trees	Wild trees	Total		
	Feet	Years	Percent	Number	Bd. ft.	Bd. ft.	Bd. ft.	Inches	Bd.ft.
132B	8x8	14	42	8	55	412	467	11.0	58
155A	10x10	14	70	13	74	709	783	11.5	59
155E	10x10	14	63	16	65	765	830	11.5	53
155G	11x11	14	84	11	254	69	323	9.2	28
101A	15x15	15	83	60	--	--	1888	9.9	31
132A	15x15	15	78	73	2504	304	2808	10.0	38
132C	15x15	15	--	62	1778	682	2460	9.9	40
163A	15x15	15	64	39	997	726	1723	10.2	44
163B	15x15	15	85	55	1876	414	2290	10.1	42
188B	15x15	15	66	42	1257	433	1690	10.3	40
101A	15x15	16	83	86	3186	122	3308	10.0	38
186A	15x15	18	75	69	3047	68	3115	10.3	45
124A	16x16	14	81	46	--	--	1481	10.0	32
124A	16x16	15	81	60	1899	176	2075	10.0	34
155I	16x16	15	86	52	1623	159	1782	10.0	34
155J	16x16	15	70	31	938	62	1000	9.9	32
163C	16x16	15	86	44	1527	133	1660	10.0	38
167A	16x16	15	65	24	737	86	823	10.1	35
220A	17x17	15	--	77	2716	51	2767	10.2	36

Figure 9.--A plus tree in one of the George Walton Plantations which has been labeled, described, and set apart for possible use in establishing seed orchards and other genetical work.

The same situation holds for the 10x10 spacing. In plantation 155A, for example, only 74 board-feet out of 783 are found in planted trees at 14 years of age. Three planted and 10 wildling trees per acre were classed as sawtimber. At 14 years of age in the 11x11 spacing, only 10 planted trees per acre, with a volume of 254 feet, were of sawtimber size and quality. On the other hand, the 15x15 spacing at 15 years of age has an average of 2265 board-feet per acre, only 375 of which are in wildlings. There is an average of 50 planted and 7 wildling sawtimber trees per acre. The 16x16 spacings have an average of 1456 feet per acre, 111 of which are in wildlings. There is an average of 39 planted and 3 wildling sawtimber trees per acre. In the 17x17 spacing the averages jump to 2676 board-feet and 75 trees per acre at 15 years of age. Although in the latter case no distinction can be made between planted and wild stock, it is known that the number of wildling sawtimber trees is negligible.

It is recognized, of course, that the more numerous wildlings in the closer spacings inhibited diameter growth to a certain extent. It is extremely doubtful, however, that the big differences in sawtimber volumes between spacings can be primarily attributed to the influence of the volunteers.

There is wide variation of sawtimber volumes within spacings. On some areas the reason for this variation is survival. On other areas where survival differences are minor, variations may be attributed to form and quality. Some plantations have more mechanical defects and are more disease-ridden than others (see section on disease and defect). Pictured in figure 9 is the type of tree that forest managers desire.

The data from these plantations illustrate the surge of "ingrowth" that occurs when the trees first reach sawtimber size. For example, plantation 101A jumped from 1888 board-feet at $14\frac{1}{2}$ years of age to 3308 at 16 years, and the number of sawtimber trees increased from 60 to 86. The tremendous board-foot growth possible in slash pine plantations is illustrated in figure 10.

The period of transformation from pulpwood to sawtimber size is a time of rapid increase in values. If an owner is operating on a short rotation, he should be on the alert and not make the mistake of liquidating prior to or during this period.

Figure 10.--A 19-year-old slash pine plantation spaced 15x15 feet. The average diameter was about 10 inches at this age, and there was a total of 7,500 board-feet of sawtimber per acre. Stumps in the foreground are from the initial thinning, which removed about 6 cords per acre.

EFFECT OF INTERPLANTING

In 1945 Mr. Walton, as usual, planted several old fields to slash pine. Thinking in terms of naval stores production, he used a spacing of approximately 15x15. A year later he reasoned that from the standpoint of pulpwood production the spacing was possibly too wide to fully utilize the growing space. To rectify this, he interplanted in one direction, assuming the one year's advantage of the first planting would have little effect on his interplants. The one year's advantage, however, has proved to have a decided effect. The interplants were so suppressed that the interplanting was a waste of money. Table 6 and figure 11 illustrate this clearly. These results have been reported in detail in "Reduction in Growth of Interplanted Slash Pine," Southeastern Forest Experiment Station Research Note Number 55, and "Interplanted Slash Pine Fails," Southern Lumberman, December 1954.

One identifiable example of replanting is found in the plantations on the experimental forest. Although this replanting was accomplished 3 years after the original planting, the results are worthy of note. An area of 5.72 acres was planted in 1942 at approximately a 10x10 spacing. Survival was low and the misses were replanted in 1945. The plantation was inventoried in 1954 when the first planting was 13 years old. The average diameter of the original planting was 6.4 inches; that of the replants 2.4 inches. Average heights were 40 and 20 feet respectively. Survival of the replants is about 35 percent. It appears certain that very few, if any, of the replants will reach merchantable size.

Table 6.--Average diameters and heights of six interplanted slash pine plantations. The second planting was made 1 year after the first

Plantation	Area	Average d.b.h. [1]		Average height [2]	
		1st planting	Interplants	1st planting	Interplants
	Acres	Inches	Inches	Feet	Feet
155C	12.15	4.7	3.5	33	24
155H	8.76	5.1	2.6	33	22
157A	15.53	4.9	3.0	32	22
157B	4.14	4.5	3.4	32	24
157C	4.09	5.0	3.5	32	20
157D	1.98	4.2	2.8	29	22
Mean		4.7	3.1	32	22

1/ 9 years after the interplanting.
2/ 10 years after the interplanting.

Figure 11.--The small trees in the center row are interplants set out 1 year after the original planting. They are rapidly being suppressed. The same suppression of interplants has occurred in six different plantations covering a range of four soil types. Plantations established from the same lot of stock that was used for the interplanting are making average growth or better.

FUSIFORM RUST INCIDENCE AND MECHANICAL DEFECT

Inventory records show that an average of 5.2 percent of the trees in the plantations listed in this report are infected with fusiform rust (Cronartium fusiforme). The degree of infection ranges from a low of 1.0 percent to a high of 16.3 percent. These figures include both limb and trunk infections, but limb cankers were not recorded unless the disease appeared likely to enter the trunk.

Table 7 illustrates the degree of infection and the percentage of forking for the various spacings. There is only slight evidence of a relationship between spacing and the degree of rust infection. Perhaps a larger sample might establish such a relationship.

Forking was the only mechanical defect recorded. An average of 1.7 percent of the trees have this defect, with a range among plantations of 0.3 percent to 5.0 percent. Forking tends to increase with spacing.

Table 7.--Percentage of planted slash pine with fusiform rust infection and forked stems

Spacing (feet)	Plantations	Rust infection	Forked trees
	Number	Percent	Percent
6x8	3	7.1	0.7
8x8	1	2.0	0.5
10x10	3	3.5	0.9
11x11	1	3.7	1.0
15x15	7	7.6	2.7
16x16	5	2.3	2.0
17x17	1	8.0	5.0

EARLY GROWTH OF PLANTED SLASH PINE

Measurements have been made for each of 3 years on the growth of field-planted slash to show the pattern in the early years (figures 12 and 13).

Height growth averaged about 0.5 foot the first year, 1.9 feet the second, and 2.9 feet the third. The third year's growth is about the average that all old-field plantings on the experimental forest have made throughout their life. Apparently it takes about 3 years for slash pine to get established and attain its level of average growth.

The time of year at which growth occurs is another point of interest. Growth by months for the year 1954 is outlined in figure 12. Approximately 60 percent of the growth was completed by April 30, and 77 percent by May 31. On these same dates in 1953, the percent of growth completed was about 55 and 68 percent respectively. In 1953 about 20 percent of the growth occurred after June 30. In 1954 about 10 percent came after this date.

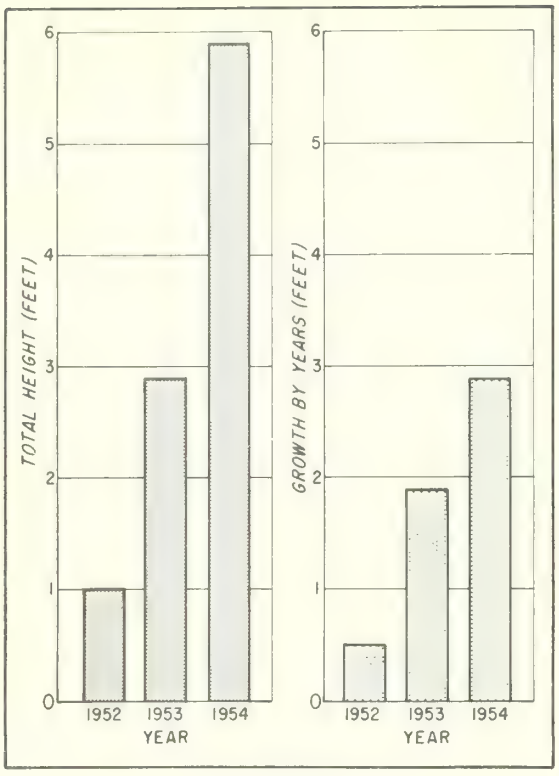

Figure 12.--Height growth of field-planted slash pine during the first 3 years after planting.

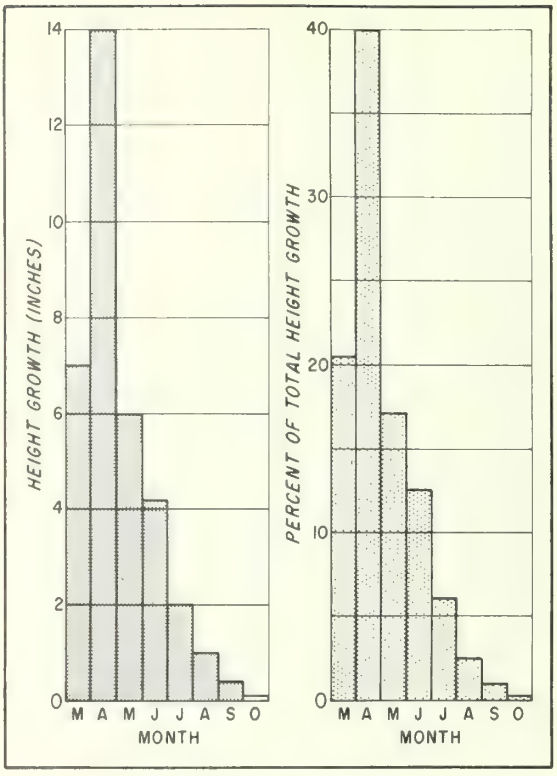

Figure 13.--Monthly height growth of field-planted slash pine during the third growing season.

OLD-FIELD VERSUS WILD-AREA GROWTH OF PLANTED SLASH PINE

In the winter of 1951-1952 two adjoining areas were planted to slash pine. One site was a field, the other a natural area supporting a very sparse stand of turpentined trees. The difference in growth between the two areas has become so apparent that a recent check was made. At the end of three growing seasons 100 sample trees from each area compared as follows:

Site	Average height (Feet)
Field	5.6
Wild area	2.6

Although the areas from which these data were gathered adjoin, the difference in growth between the two sites is not restricted to this particular location. All comparisons show that growth of field plantings has far surpassed that of plantings in wild or natural areas on the experimental forest. Figure 14 illustrates the difference in growth between the two sites.

Figure 14.--The above pictures, taken less than 100 yards apart, illustrate the difference in growth between cutover areas (left) and old-field sites (right). The pictures were made at the end of the third growing season.

SUMMARY

Summary data from 21 slash pine plantations on 70- to 80-foot sites, George Walton Experimental Forest, Dooly County, Georgia, show the annual diameter growth to average 0.53 inch up to 18 years, the annual height growth to average 2.9 feet, and the annual cordwood growth to average 1.2 cords. Diameter growth varies directly with spacing, and yield correlates closely with survival and site index. If fire history and site are similar, the difference in cordwood growth between spacings is not pronounced. Different spacings, however, resulted in highly significant differences in early production of board-foot volume. Only the wider spacings produced appreciable sawtimber volume by 15 years of age.

Fusiform rust infection bore only slight relationship to spacing. On the other hand, forking appears to increase with spacing. Observations further show that slash pine interplanted one year after the original planting is subject to early suppression, and that attempts to reinforce stands of 175 trees or more per acre are likely to meet with little success. The big difference in early height growth between trees on old-field and cutover areas is demonstrated.

APPENDIX

The following soils descriptions are taken from the descriptions submitted by the Soils Correlation Committee of the Bureau of Plant Industry, Soils and Agricultural Engineering, Knoxville, Tennessee. Mr. A. H. Hasty of this committee made the field survey.

Cuthbert Sandy Loam

Surface soil: 4 to 16 inches deep gray to dark grayish-brown, friable sandy loam; moderate organic content. Quartz gravel up to 5 inches in diameter found in local areas.

Subsoil: Yellowish-red to yellowish-brown, firm to friable sandy clay loam.

Drainage: Surface runoff medium to high, internal drainage medium to slow.

Gilead Loamy Sand

Surface soil: 10 to 18 inches deep in most phases, although it may range from 18 to 30 inches in the thick phases; very dark-grayish brown to olive brown, loose loamy sand with small organic content in upper level.

Subsoil: Yellowish-brown to reddish-yellow firm sandy clay that becomes plastic when wet. Strong mottling between 26 and 42 inches.

Drainage: Surface runoff medium to rapid, depending upon slope; internal drainage rapid in upper level but moderate to slow in lower.

Lakeland Loamy Sand

Surface soil: 30 to 40 inches deep; grayish-brown to yellow, loose loamy sand. Small amount of organic matter in first 6 inches.

Subsoil: Yellow mottled with strong brown, light gray, and red firm to very firm sandy clay.

Drainage: Surface runoff usually high; internal drainage rapid.

Mayhew Sandy Loam

Surface soil: Very dark-gray friable sandy loam with a fairly high organic content.

Subsoil: Grayish-brown to light-gray firm to very firm sandy clay mottled with strong brown, reddish-yellow, and pale olive. Part of the material has appearance at lower levels of low-grade Fuller's earth.

Drainage: Surface runoff low; internal drainage slow.

Susquehanna Loamy Sand

Surface soil: 3 to 16 inches deep dark grayish-brown loose loamy sand to sandy loam with small organic content.

Subsoil: Light yellowish-brown to red clay mottled with red, light-gray, reddish-yellow, and pinkish-gray. Very plastic when wet. At 42 inches the material becomes more purplish and gray.

Drainage: Surface runoff medium to high; internal drainage slow to very slow.

Table 8.--Growth and survival of individual slash pine plantations by spacing, soil type, and age

Plantation number	Spacing	Soil	Site index	Age	Area	Trees planted per acre	Survival	Average d.b.h. 1/	Maximum height 1/	Average height 1/	Mean annual growth per acre 2/	Basal area per acre 2/
	Feet	Type	Feet	Years	Acres	Number	Percent	Inches	Feet	Feet	Cords	Square Feet
187A	6x8	Gilead loamy sand	80	5	15.06	907	(3/)	2.2	17	11	--	11.013
187B	6x8	Gilead loamy sand	4/ 80	5	5.31		(3/)	2.1	18	12	--	22.383
131A	6x8	Cuthbert sandy loam	70	5	9.03		(3/)	2.4	19	12	--	22.970
			(80)	8			71	4.0	34	26	0.55	60.331
132B	8x8	Gilead loamy sand	80	6	2.36	680	(3/)	2/ 2.5	18	13	6/ 0.56	24.864
			(65)	14			5/ 42	5.7	49	41	0.95	59.910
155A	10x10	Cuthbert sandy loam	70	8	8.81	436	73	3.2	24	17	6/ 0.26	26.671
			(68)	14			70	6.0	48	40	1.31	75.423
155E	10x10	Gilead loamy sand	80	8	4.19		64	3.5	26	18	6/ 0.78	29.151
			(68)	14			63	6.2	47	39	1.31	73.724
155D	10x10	Lakeland loamy sand	76	4	21.81		78	2.1	16	11	--	9.250
			(73)	11			75	6.1	43	35	1.42	69.304
155G	11x11	Cuthbert sandy loam	70	8	2.68	360	85	3.4	24	17	0.09	21.919
			(68)	14			84	6.7	47	37	1.46	80.038
132A	15x15	Lakeland and Gilead loamy sands	76	7	9.23	194	(7/)	2/ 5.1	34	24	0.58	23.647
			(73)	15			78	8.5	58	47	1.31	67.329
132C	15x15	Gilead loamy sand	80	7	7.72		91	4.7	34	25	0.77	5/ 30.753
			(75)	15			85	7.8	56	49	1.38	5/ 73.811
163A	15x15	Mayhew loamy sand	--	9	3.88		67	4.4	36	23	0.36	5/ 19.612
			(71)	15			64	7.3	56	41	0.91	5/ 49.100
188B	15x15	Susquehanna and Cuthbert loamy sands	69	9	11.48		(7/)	2/ 4.5	32	26	0.23	15.576
			70	16			66	8.1	55	45	1.01	56.667
186A	15x15	Gilead loamy sand	80	10	22.28		(7/)	2/ 5.2	38	24	0.50	5/ 25.748
			(68)	18			75	9.0	60	48	1.15	8/ 69.669
101A	15x16	Gilead loamy sand	80	9	56.50	181	83	5.9	40	29	0.75	5/ 31.892
			(77)	11			(7/)	2/ 6.5	--	--	1.03	44.640
				15			(7/)	2/ 7.8	65	49	1.15	64.838
				16			83	9.0	68	52	1.36	63.052
163B	15x16	Gilead loamy sand	80	9	12.35		87	5.2	38	27	0.65	5/ 29.948
			(72)	15			85	8.2	55	46	1.30	67.579
124A	16x16	Lakeland and Gilead loamy sands	76	8	25.69	170	81	5.0	36	26	0.50	5/ 23.447
			80	14			81	8.3	59	46	8/ 1.26	61.304
			(75)	15			81	8.6	63	49	1.23	63.243
155I	16x16	Gilead loamy sand	80	8	4.90		88	5.1	30	23	0.46	21.961
			(71)	15			86	8.7	54	45	1.33	68.070
155J	16x16	Gilead and Susquehanna loamy sands	80	8	8.80		80	4.0	28	19	0.32	17.413
			69	15			70	8.4	58	43	1.00	52.481
			(70)									
163C	16x17	Lakeland and Gilead loamy sands	76	9	22.67	160	87	5.2	36	26	0.48	5/ 23.384
			80	15			86	8.4	51	43	1.13	58.045
			(69)									
167A	16x17	Gilead loamy sand	80	9	25.54		68	4.0	28	18	0.36	5/ 18.01
			(64)	15			65	7.9	49	39	8/ 0.77	40.937
220A	17x17	Lakeland and Gilead loamy sands	76	8	14.89	151	(7/)	2/ 5.5	40	31	0.79	30.549
			80	15			(7/)	2/ 6.8	59	49	1.46	77.152
			(78)									

1/ Includes planted trees only, except where noted.
2/ Includes planted trees and wildlings.
3/ Survival cannot be determined because only trees 0.6 inch and over were tallied.
4/ The figure without parentheses represents the average site index of natural slash pine stands growing on the same soils on the experimental forest. The figure in parentheses is the projected height of the planted trees at 25 years of age as read from Barnes and Ralston's site quality curves in "Soil Factors Related to Growth and Yield of Slash Pine Plantations," Fla. Agr. Expt. Sta. Bul. 559, 1955. Where a plantation area is made up of two soil types, the site index of each type is given.
5/ Plantation suffered one or more severe burns.
6/ Numerous merchantable wildlings bolstered yield despite poor survival of planted stock.
7/ Survival data unavailable.
8/ Several merchantable wildlings cut between inventories.

Agriculture--Asheville

Station Paper No. 67 May 1956

Forest Insect Conditions in the Southeast During 1955

by
E. P. Merkel
and
R. J. Kowal

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

FOREST INSECT CONDITIONS IN THE SOUTHEAST DURING 1955

by

E. P. Merkel and R. J. Kowal

INTRODUCTION

The southern pine beetle continued its destruction during 1955 in western North Carolina and eastern Tennessee, though at a lower level than in 1954. It was discovered for the first time in the northern counties of South Carolina and Georgia. Ips engraver beetles, attracted by the fire-ravaged woodlands of south Georgia, added their own destruction to the already staggering losses. It hit in other areas too, particularly in south-central North Carolina and north-central South Carolina. It was also active in north Florida. Throughout the Southeast, but particularly in south Georgia and north Florida, the black turpentine beetle continued its destructive activities, building up populations especially in fire-damaged areas.

Planting programs also suffered from insects; the pales weevil, associated weevils, white grubs, and tip moths were particularly damaging. Other insects not so conspicuous as the bark beetles have caused losses which, in the aggregate, are very substantial. There are, however, numerous encouraging signs in the forest insect situation.

PROGRESS IN FOREST ENTOMOLOGY

With the enlargement of the Station's Division of Forest Insect Research, the forest insect survey program in the Southeast became considerably more effective than at any time previously. The program's basic purpose is to develop in foresters and forest landowners a knowledge and consciousness of forest insect pests, which in turn will result in early detection of insect outbreaks. This is intended, insofar as possible, to prevent the development of forest insect epidemics. Its purpose too, is to stimulate interest in the entire field, so that losses may be reduced and forest insect research increased.

Information.--Numerous meetings were held throughout the Southeast to inform foresters about forest insects. Discussions were illustrated with colored slides and specimen mounts. In many cases field demonstrations were held. This type of information was presented to undergraduate forestry students and to forestry graduates attending short courses and meetings. Similar programs have been presented to civic clubs and other organizations to acquaint them with our activities as much as with the forest insect problems.

Forest Insect and Disease Newsletter.--During this year, the Division began to issue a newsletter to keep foresters informed of forest insect activities and the measures they should apply to prevent or control the insects. It is issued whenever the forest pest situation demands it.

Forest Pest Committees.--The formation of such committees has been encouraged as an aid to stimulate action of individuals and organizations in the detection and control of forest pests. The Georgia Forest Pest Committee was formed this year to deal with Georgia's problems. A Southern Pine Beetle Committee has been formed to coordinate efforts and information in connection with the beetle problem in western North Carolina and eastern Tennessee. Separate State Pest Committees in both of these states are now under consideration.

Employment of entomologists by states and industry.--A few years ago, Virginia and North Carolina employed specialists to handle their insect and disease problems. Since then, agencies in Georgia have financed the employment of a forest entomologist and very recently the State of Tennessee employed an entomologist. About a year ago Union Bag and Paper Corporation set a precedent by being the first southern industry to employ a forest entomologist, and Bowaters Southern Paper Corporation has just employed a man to fill a similar position. Indications are that other states and industries are considering similar action.

At present the function of these specialists is to give their attention to critical problems which have built up over the years. However, when these problems are gradually brought under control the efforts of these men will be guided toward survey and research programs to develop methods of growing timber without the ever-present threat of insect attack.

STATUS OF DESTRUCTIVE FOREST INSECTS IN 1955

Southern Pine Beetle

It is estimated that 15.5 million board-feet of pine sawtimber and 42,100 cords of pole timber were killed (table 1) by the southern pine beetle, Dendroctonus frontalis Zimm., from central and western Virginia through the Southern Appalachians and Blue Ridge Mountains into northern Georgia and South Carolina in 1955. This figure does not include losses incurred in Kentucky, where the insect has been active during the past 4 years.

North Carolina and Tennessee.--During 1955 in North Carolina and Tennessee a total of 179,700 trees were killed on lands where control operations were in progress. No figure is available for losses on noncontrol lands, which primarily included small private ownership. Of these trees, 136,600 were on the Cherokee and North Carolina National Forests; 61,900 were salvaged and 74,700 were felled and sprayed with $\frac{1}{4}$ percent gamma BHC in fuel oil. About 16,900 infested trees in the Great Smoky Mountains National Park, Cherokee Indian Reservation, and Blue Ridge Parkway (N.C.) were sprayed.

Table 1.--Volume of pine timber killed by major bark beetles in the Southeast [1/] 1952-1955

Year [2/]	Southern Pine Beetle		Ips Engraver Beetle		Black Turpentine Beetle	
	Pole timber	Saw-timber	Pole timber	Saw-timber	Pole timber	Saw-timber
	Thousand cords	Million bd. ft.	Thousand cords	Million bd. ft.	Thousand cords	Million bd. ft.
1952	14.2	5.4	129.4	103.3	7.8	8.5
1953	21.7	9.8	129.4	103.3	7.8	16.5
1954	60.6	22.5	279.5	177.0	7.8	45.0
1955	42.1	15.5	190.0	118.8	7.8	37.0
Total	138.6	53.2	728.3	502.4	31.2	107.0

1/ Southeast includes the entire states of Virginia, North Carolina, South Carolina, Georgia, and Florida.

2/ The data for 1952 were obtained from the "Timber Resources Review," and losses for that year were considered normal or near normal. Data for 1953-1955 show endemic plus epidemic mortality.

On private lands some beetle control is in progress, but there is a great deal of room for improvement. Fortunately, uncontrolled outbreaks are primarily in small tracts of forest land and do not endanger land under organized control. There is an appreciable amount of control going on in some private lands, particularly salvage in North Carolina as a result of efforts of forest industry and public agencies. Through lectures and news articles, landowners have been and are being advised of the problem, their trees are marked, and a market found for their wood.

Toward the end of the year another outbreak was discovered in Tennessee on the Tellico Ranger District, an area quite apart from other infestations. Control possibilities and the high value of timber justified a control project, much of which consists of salvage.

The reduction in the severity of the epidemic has been substantial since large-scale control programs began about a year ago. In a number of large control units, outbreaks have been wiped out or are negligible. In the Smoky Mountains National Park, for example, there were about 26,000 infested trees in March 1955; now there are about 3,000.

South Carolina.--In August some killing by the beetle was observed to be concentrated in Union County, extending into all counties surrounding it. The situation was so confused by mortality from Ips, littleleaf disease, drought, and just poor site conditions that no attempt was made to set up a control program. However, observation of the area was maintained to detect any unusual extension of the southern pine beetle in adjacent lands.

In October, outbreaks were spotted in Pickens County, particularly on the Sumter National Forest. Conditions justified a control program, which was set up as soon as possible. State and extension foresters were advised of conditions on private land and took action in the matter.

Georgia.--Toward the end of the year outbreaks were reported and confirmed from the counties of extreme north Georgia including the Chattahoochee National Forest. An aerial survey has been planned. A rather positive report was very recently received from LaGrange and confirmed; this may well be a fringe attack from the epidemic area around Talledega, Alabama.

Kentucky-Virginia.--Not a great deal is known regarding the status of the beetle in these two states except that it is more or less active. Aerial observation in Virginia in March 1955 revealed substantial killing in an area of about 700,000 acres in the central part of the State. An intensive aerial check in May defined the epidemic area; however, ground checks revealed very low beetle populations. Since then, scattered outbreaks have been reported, but these have not been severe. The Division is working very closely with the entomologist from the State Forester's office in following developments.

In Kentucky no great losses have taken place. However, the State Forester's office is very active in cleaning up outbreaks early in their development and recommending such activity to private owners.

General.--A study of southern pine beetle outbreaks in the Southeast to date shows that outbreaks become quite severe in the heart of the Southern Appalachians and decrease in their intensity at fringe areas of the mountains (figure 1).

Pine Engraver Beetle

Although the Ips beetles have caused much less region-wide damage this year than during the exceptionally dry 1954 season, it was estimated that 118.8 million board-feet and 190 thousand cords of southern yellow pine were killed in the Southeast by these bark beetles (table 1).

Most of the volume killed in 1955 occurred in southern Georgia and Florida, where soil and water-table moisture conditions were still subnormal. Large wildfires, intermittent summer cutting, lightning, and naval stores operations were contributing factors to small outbreaks in limited areas. In many localities, abnormally high engraver beetle populations were maintained in stands affected by persistent black turpentine beetle attacks. Rather serious losses also occurred in south-central North Carolina and north-central South Carolina.

Black Turpentine Beetle

The black turpentine beetle, Dendroctonus terebrans (Oliv.), was second only to the pine engravers in the total volume of pine killed by bark beetles in the Southeast during 1955. It was estimated that at least 37 million board-feet of sawtimber was killed in 1955, most of this in southern Georgia and northern Florida.

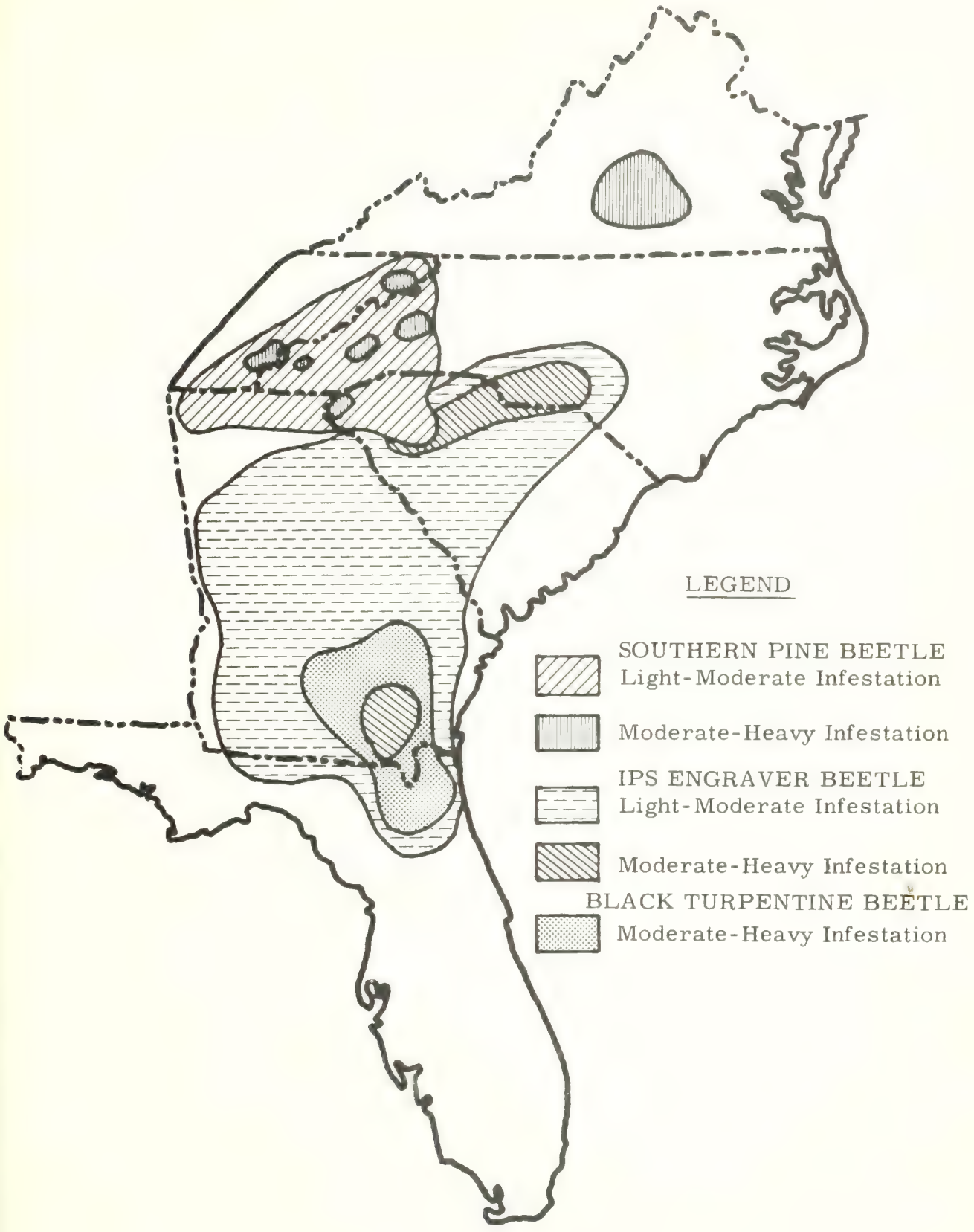

Figure 1.--Major infestations of bark beetles in the Southeast during 1955.

The 1-percent gamma BHC fuel oil spray developed at the Lake City Research Center received wide use by turpentine operators in Georgia and Florida this year, and good results have been reported to date.

Despite the fact that most naval stores leases have been terminated on the Osceola National Forest, Florida, during the past few years because of heavy beetle-caused mortality in turpentine orchards, it was necessary to spray 6,000 non-faced, infested trees during the last half of 1955. Naval stores operations will be resumed in 1956 but limited to 1 crop (10,000 faced trees). This operation will be observed closely for black turpentine beetle attack in 1956.

This beetle has shown greater aggressiveness in the northern part of its range this year than during the past two seasons. In North Carolina, for example, an 18-year-old loblolly pine plantation in the north-central Piedmont was severely damaged, and heavy attacks are currently active on the Croatan National Forest. The beetle has been reported frequently from north Georgia, Tennessee, Kentucky, and Virginia.

In many instances the beetle has followed other forest depredations such as southern pine beetle or fire, which provide large amounts of breeding material. This is, of course, characteristic of the beetle's behavior.

Pine Reproduction Weevils

Three pine weevils, Hylobius pales (Hbst.), Pachylobius picivorus Germ., and Pissodes nemorensis Germ., particularly the first two, are increasingly damaging plantations, according to reports from every state in the Southeast. Damage consisting of adult feeding on stems of seedlings has varied from a negligible figure to 80-90 percent mortality. It has been most severe in plantings following cutting--a practice which is increasing. The beetles are also attracted to burns, and young pine in the vicinity may suffer injury or death. Pales and Pachylobius appear to be very closely associated; some reports indicate that the latter, a larger weevil, is more common and more destructive. Pissodes nemorensis is less frequently associated, but is not uncommon. Damage to young seedlings is usually fatal; seedlings 3 years and older generally survive except when attacked by Pissodes, which is capable of killing older reproduction, since its immature stages breed under the bark. Considerable research on control of these insects is in progress. Treatment of the plant by a dip in 2-percent aldrin or heptachlor emulsions is promising, as is the application of granular insecticides around the base of the seedling. Cutting and planting schedules are being studied as control techniques, since delayed planting is generally not practical.

Nantucket Pine Moth

This year, as in 1954, the pine moth, Rhyacionia frustrana (Comst.), has caused widespread damage to young pine in the Southeast. The Piedmont area of North Carolina, South Carolina, and Georgia has been particularly hard hit.

The effect of tip moth damage on pine is still questioned. Studies conducted by different researchers generally confirm the fact that infestation under average conditions causes 6 to 12 inches growth loss per year. A very heavy attack on a very poor growing site causes much more severe effects to the point of dwarfing.

General observations over the South during several years strongly indicate that generally the severity of infestation varies directly with the vigor of trees, as it is influenced by drought, site, and related environmental factors (size of insect populations, of course, plays a dominant part).

Success in control has been obtained experimentally and in practice by spraying with the chlorinated hydrocarbons such as DDT and benzene hexachloride. This may be impractical in large plantations or in plantings subject to contamination from adjacent untreated areas.

Four-eyed Spruce Bark Beetle

This bark beetle, Polygraphus rufipennis (Kirby), was found associated with the southern pine beetle in red spruce near Mt. Mitchell, North Carolina. Groups of spruce were attacked by the southern pine beetle, but the insect failed to develop broods; the four-eyed spruce beetle followed, developed normally, and aided in killing the tree. Large populations later developed which were capable of killing spruce without southern pine beetle association. Such outbreaks were local and shortlived.

Hickory Bark Beetle

During the severe drought year 1954, this bark beetle, Scolytus quadrispinosus Say., killed thousands of hickory trees over a 6-county area in the extreme southwest Piedmont Region of North Carolina. Because of the irregular distribution of hickories in forest stands and as shade trees, trees were seldom killed in large groups.

In 1955, mortality caused by this beetle was common but approached endemic levels. Dead and dying twigs and branches were frequently reported from this area as a result of the feeding of adult beetles.

Pith Boring Bark Beetle

Pityophthorus pulicarius (Zimm.), caused much concern again in 1955. At the Lake City, Florida, Research Center this small beetle attacked and killed valuable scions of grafted slash pine being prepared for seed-orchard establishment as part of the forest genetics project.

Pine Leaf Aphid

The pine leaf aphid, Pineus pinifoliae (Fitch.), is a sucking insect which causes dying of branch tips and sometimes death of suppressed seedlings of white pine; it has a complete life cycle on red spruce and white pine. During

May-June 1951, it caused serious damage in the mountains of western North Carolina. Occurring on white pine during odd-numbered years, the infestation expected in 1955 did not materialize.

Pine Pitch Moth

The larvae of a species of Dioryctria (possibly amatella) was found boring into freshly made wounds or small turpentine faces in experimental gum yield plots at Lake City, Florida. A 1-percent gamma BHC oil spray application appears to have prevented the moth from attacking fresh wounds for at least 3 months.

White Grubs

In 1954 considerable damage to recently planted pine seedlings caused by Phyllophaga spp. occurred in a tree-planting project on lands of the Atomic Energy Commission at Aiken, South Carolina. In 1955 damage was very light and population counts revealed light and erratic grub distribution. While the white grub problem is common in pine nurseries, to date it has been relatively uncommon in plantations. With increased planting of agricultural lands, however, the problem may well become more severe. Therefore, control of the insect is being studied, and certain synthetic organic insecticides appear promising.

Pine Sawflies

A few reports of very localized infestations of Neodiprion spp. were received from almost every state in the Southeast during 1955. The red-headed pine sawfly, Neodiprion lecontei, was most frequently reported on longleaf, slash, and loblolly pines. Due to recent clarifications in the taxonomic status of the genus Neodiprion, it is hoped that future sawfly damage will be more accurately reported as to species distribution and host plant preference.

Cypress Flea Beetle

During mid-June to late August 1954, feeding by the adult Systena marginalis (Illinger) caused severe discoloration of 80 to 90 percent of the cypress foliage over 14 counties in southeast Georgia and northeast Florida. What had been thought to be drought injury was actually insect feeding.

In 1955, observations revealed that the damage was approximately 50 percent less than in 1954 over the same area.

Records of the National Museum show that this species is widely distributed over the eastern United States from New Hampshire to Florida and Alabama. It has been reported as feeding on clover, peach, and fire cherry, in addition to cypress.

Although the effects of the beetle's feeding on cypress have not been investigated, it is suspected that the damage could have an adverse effect on growth and survival, particularly during drought or other severe environmental upsets.

Fall Cankerworm

Following 3 consecutive years of heavy hardwood defoliation throughout the Southern Appalachians, infestations of the fall cankerworm, Alsophila pometaria (Harr.), were reduced to small localized centers during 1955. Late spring freezes and moderate egg parasitization appears to have largely accounted for the natural control of the outbreak. It has been difficult to differentiate the limited tree mortality observed in fall cankerworm defoliated areas from severe drought. However, there have been claims of considerable tree mortality caused by this insect in West Virginia in 1955. In control studies, a 2.5 percent DDT spray applied to the trunk to prevent egg-laying appeared only partly successful. A DDT mist spray applied to the foliage to kill larvae appeared more effective.

Orange-striped Oakworm

The larvae of this moth, Anisota senatoria (Smith), were commonly found stripping individual trees and small scattered clumps of oaks throughout the Southern Appalachians in 1955 as in 1954. An unidentified virus or bacterial wilt disease appeared to be an effective natural control in many larval colonies this year.

Mimosa Webworm

Although not a forest pest, the larvae of this moth, Homadaula albizziae, Clarke, causes serious defoliation of ornamental mimosa trees. Increased observation of this damage during 1954 and 1955 indicate a strong movement into western North Carolina, where 3 to 4 years ago infestations were very light.

Agriculture--Asheville

tation Paper No. 68 August 1956

Outline for Compiling Precipitation, Runoff, and Ground Water Data from Small Watersheds

by *Edward A. Johnson*

and *Robert E. Dils*

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

This is a revision of Technical Note No. 34, first issued in 1938 by C. R. Hursh. Reissues in 1939 and 1940 included numerous valuable suggestions for improvements from co-workers in the field of small drainage-area studies. Since the last issue in 1940, additions and deletions in both procedures and forms have been effected. In the present edition these changes have been brought up to date and more recent techniques and methods added; also a new section in ground water inventories.

This outline represents the efforts of the field and office staffs and technicians of the Division of Watershed Management at the Southeastern Forest Experiment Station, and acknowledgment is made to all who have been associated with this Division.

ABBREVIATIONS

c.f.	=	cubic feet
c.f.s.	=	cubic feet per second
c.s.m.	=	cubic feet per second per square mile
gal.	=	gallons
gpd.	=	gallons per day
mgd.	=	million gallons per day
a./f.	=	acre feet
in./hr.	=	inches per hour

WATER UNITS

1 cubic foot = 7.4805 gallons
1 acre foot = 43,560 cubic feet
1 acre foot = 325,851 gallons
1 acre inch = 3,630 cubic feet
1 acre inch = 27,154 gallons

1 cubic foot per second = 646,317 gpd.
1 cubic foot per second per day = 1.9835 a./f.
1 gallon per minute = 1440 gpd.
1 million gallons per day = 1.5472 c.f.s.

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ERRATA

Page 34, formula (1), please substitute $Q = Q_o e^{-kt}$ for Q = Qoe - kt

Page 34, line 9 from bottom, please substitute 0.362216 for 0.36226.

OUTLINE FOR COMPILING PRECIPITATION, RUNOFF, AND GROUND WATER DATA FROM SMALL DRAINAGE AREAS

by

Edward A. Johnson
Southeastern Forest Experiment Station

and
Robert E. Dils
School of Natural Resources, University of Michigan

INTRODUCTION

Studies of small drainage areas directed toward a better understanding of the relationships between land management practices and water resources are among the best bases for intelligent management of water once it falls on the land as precipitation. Information derived from such studies serves as a basis upon which to plan for water conservation, and for agricultural, municipal, industrial, and recreational needs.

Before any resource can be managed properly, an inventory is necessary. A complete inventory or accounting for all forms of water recharge and water discharge for any drainage area would require a thorough analysis of all phases of the hydrologic cycle including precipitation losses due to interception by vegetative canopies, evaporation and transpiration losses, soil moisture retention, and all forms of ground water seepage. Many years of systematic research will be required before all these phases of the hydrologic cycle will be accounted for accurately. Fortunately, certain of the more easily measured phases do furnish a fairly reliable basis for interpreting important trends in the water economy of small drainage areas. Three such measurements are precipitation, runoff or streamflow, and ground water storage. These measurements are the primary steps in studies of small drainage areas. They also assist in orienting the research needs for other less easily measured phases of the hydrologic cycle.

This outline describes a basic inventory method for the systematic compilation of data on precipitation, streamflow, and ground water. It is based on over 20 years of experience with small drainage areas at the Coweeta Hydrologic Laboratory, in the Southern Appalachian Mountains. As an aid in subsequent analysis work, much of the data is compiled to correspond with the growing and dormant seasons, i.e., from May to October and November to April, respectively, or to correspond with the following hydrologic seasons:

May-September, period of maximum evaporation and transpiration;
October-December, period of soil moisture recharge;
January-April, period of ground water recharge.

PRECIPITATION

Since approximately 98 percent of the precipitation received on the Coweeta Hydrologic Laboratory occurs in the form of rain, the treatment of precipitation in this paper is restricted to the compilation of rainfall data.

Two measurements of rainfall are commonly made in hydrologic as well as meteorologic studies: first, total rainfall, in which the U. S. Weather Bureau standard rain gage is used, and second, rainfall intensity, where a recording gage is used.

STANDARD RAIN GAGE DATA

Trail Forms a and b

The original field measurements of rainfall collected in the standard rain gages are tabulated on Trail Form a. In addition to the depth of rain in inches, the rain gage number, date of rain, date of the gage reading, time of the reading, and any pertinent remarks are all recorded on the trail form. The original field or trail forms are filed for permanent reference.

For major storms, or all storms yielding over 2 inches of rain, a supplemental form, Trail Form b, is used along with Trail Form a. On line 1, the gage number is entered. On line 2, a check measurement is entered. This consists of the stick reading in inches and hundredths of inches in the 8-inch cylinder after the full 2-inch core has been removed. On line 3, 2.00 inches is ordinarily entered for the volume of water in the full 2-inch core. The water in this core is thrown out and the core is filled nearly full from the water remaining in the 8-inch cylinder. This volume is measured and the value recorded on line 4. If more water remains, the process is repeated and the volume recorded on line 5. The column is then totaled (starting with line 3). This total is entered on line 6 and also in the appropriate column on Trail Form a. If more than 6 inches of rain is measured, use another column to record the values on Trail Form b.

Storm Separation

It is not always practicable to read each standard rain gage immediately after a storm, and quite often a second storm occurs before a measurement can be made. For individual storm studies it is then necessary to separate the amount of rainfall attributed to each storm. To make such separations, the chart from the recording rain gage nearest to a standard gage is examined and the amount of rainfall attributed to each storm is calculated. The percentage of rainfall for each storm is computed, and these percentages are then applied to the standard gage readings. Data at the head of page 4 illustrate this method of storm separation.

Trail Form a

U. S. Department of Agriculture Trail Form a
Forest Service
Experimental Area Coweeta
RI-SE
Water Relations
Precipitation
Name of Trail Wildcat

Gage No.	Date of rain	Date of reading	Time of reading	Reading (Inches)	Observer initials	Remarks
14	3/10-11/52	3/11/52	0920	5.72	JS	See Trail Form b
39				5.56		
50				4.92		
69				4.98		
7				7.20		
8				6.51		
9				6.67		
12				4.26		
18				4.63		
20				5.40		
21				4.66		
25				4.15		

Trail Form b

U. S. Department of Agriculture Trail Form b
Forest Service
Experimental Area Coweeta
RI-SE
WATER RELATIONS
Precipitation
Name of Trail Wildcat

Gage No.	(1)	14	39	50	69	7	8	9	12	18
Check	(2)	3.70	3.60	2.90	3.00	5.10	4.50	4.65		
2" core	(3)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Refill-1	(4)	1.95	1.90	1.97	1.93	1.90	1.95	1.89	1.94	1.90
Refill-2	(5)	1.77	1.66	.95	1.05	1.92	1.96	1.96	.32	.73
Total	(6)	5.72	5.56	4.92	4.98	-	-	-	4.26	4.63
Gage No.	(1)	20	21	25		7	8	9		
Check	(2)					-	-	-		
2" core	(3)	2.00	2.00	2.00		-	-	-		
Refill-1	(4)	1.94	1.95	1.97		1.38	.60	.82		
Refill-2	(5)	1.46	.71	.18		-	-	-		
Total	(6)	5.40	4.66	4.15		7.20	6.51	6.67		
Gage No.	(1)									
Check	(2)									
2" core	(3)									
Refill-1	(4)									
Refill-2	(5)									
Total	(6)									

Storm	Recording rain gage values	Percentages	Standard rain gage values		
			No. 21	No. 20	No. 18
	Inches		Inches	Inches	Inches
Total	5.40	100	5.38	5.50	5.27
Storm 1	1.65	30.6	1.65	1.68	1.61
Storm 2	3.75	69.4	3.73	3.82	3.66

Monthly Record of Standard Rain Gages--Form 1

The next step in the compilation of standard rain gage data is to summarize individual storm values by months. Rainfall data for each gage and for each storm are entered on Form 1, which shows the dates rainfall occurred, the corresponding dates on which the gages were read and the amount of rain recorded in inches. The rainfall columns are totaled to give the total monthly rainfall for each gage. If the individual storm values were derived by storm separation rather than directly from the trail form, this is indicated in the remarks column.

Annual Summary of Standard Rain Gage Data by Months

Another step in the recording of data from the individual standard rain gages is the annual summary by months (see following summary). Supplemental information in addition to the actual rainfall data by months and years might be the elevation at the gage location, the rise in feet from the gage location to the top of the ridge, the azimuth of the exposure, and the slope distance from the gage location to the top of the ridge, as well as the recording rain gage used for storm separations, and the watersheds which the gage services.

Record of Weighted Mean Precipitation on an Individual Drainage Basin

Since most drainages require more than one gage for adequate sampling, precipitation in area inches is derived from a weighted mean of all gage measurements. Form 2 is used for this computation.

The Horton-Thiessen Mean Method [1/] is ordinarily used for estimating the weighted area inches of rainfall. This method consists of applying to each standard gage reading a weight factor which is the percentage of the total drainage area lying closer to this gage than to any other gage. The rain gage service area, represented by each standard rain gage, is determined by geometric construction and planimetering. Each rain gage reading is applied to an area bounded by either the perpendicular bisectors of the lines connecting each gage to adjacent gages, or by the boundary of the drainage area, or by both. Figure 1 illustrates the method of determining rain gage service areas.

1/ Horton, Robert E. Accuracy of areal rainfall estimates. Monthly Weather Review 51: 348-353. 1923.

RI-SE
WATER RELATIONS
Precipitation
Experimental Area Coweeta

U. S. Department of Agriculture
Forest Service
MONTHLY RECORD OF
STANDARD RAIN GAGES

Form 1
File No. 3.131

Date		Rain gage number												Remarks
Read	Rain of	14	39	50	69	7	8	9	12	18	20	21	25	
3/4	2,3,4	2.70	2.46	2.43	2.73	2.96	3.16	2.80	2.42	2.45	2.56	2.54	2.46	
3/11	10, 11	5.72	5.56	4.92	4.98	7.20	6.51	6.67	4.26	4.63	5.40	4.66	4.15	
3/19	18, 19	1.82	1.71	1.50	1.61	2.13	2.12	1.95	1.47	1.52	1.69	1.45	1.33	
3/23	21	1.70	1.54	1.56	1.78	1.68	1.94	1.81	1.53	1.61	1.68	1.63	1.48	*
3/23	22, 23	4.40	3.98	4.02	4.61	4.07	4.69	4.88	3.51	3.66	3.82	3.75	3.42	*
3/25	23	.17	.22	.16	.17	.15	.18	.20	.19	.18	.17	.17	.17	*
3/25	24	.21	.27	.20	.21	.28	.34	.38	.29	.23	.22	.26	.26	*
4/2	31	.22	.19	.20	.27	.33	.37	.37	.16	.23	.23	.17	.17	
Monthly totals		16.94	15.93	14.99	16.36	18.80	19.31	19.06	13.83	14.51	15.77	14.63	13.44	

*Asterisk indicates all storms determined by storm separation

Month March Year 1952

Recorder C. L. Shope

Sheet 1 of 1

RI-SE
WATER RELATIONS
Precipitation
Expt. Area Coweeta

File No. 3.134

U. S. Department of Agriculture
Forest Service
ANNUAL RECORD BY MONTHS FOR AN
INDIVIDUAL STANDARD RAIN GAGE

(In inches)

Standard Rain Gage No. 39

Computed by B.C.
Checked by E.A.J.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Mean
1935	7.70	3.81	5.79	6.16	4.09	3.58	8.65	10.58	1.31	2.57	8.06	6.34	68.64	
1936	14.50	9.45	6.59	10.46	2.56	2.94	7.36	6.57	8.85	5.02	2.04	12.39	88.73	
1937	12.43	6.35	3.10	7.76	2.27	5.53	3.92	4.73	2.83	9.14	2.86	6.30	67.22	
1938	5.03	2.76	9.83	5.27	6.39	6.89	12.18	1.75	3.32	.16	11.60	3.26	68.44	
1939	4.41	12.63	7.90	5.31	3.03	3.38	6.36	6.23	1.10	.92	.83	3.92	56.02	
1940	2.96	7.38	5.28	7.31	2.36	7.26	4.20	13.89	.91	1.90	5.91	4.86	64.22	
1941	3.44	1.64	5.45	3.51	1.41	3.27	10.35	3.43	3.40	2.92	4.69	8.61	52.12	
1942	5.32	6.33	9.35	1.00	9.71	3.40	9.80	4.05	6.48	3.58	2.68	13.00	74.70	
1943	7.41	5.04	9.41	6.17	4.13	6.48	11.86	5.10	5.26	2.64	2.44	4.36	70.30	
1944	4.54	12.03	12.46	6.87	4.73	1.47	3.91	6.44	7.56	1.15	5.74	7.39	74.29	
1945	2.62	8.22	5.73	8.44	3.20	3.11	3.45	3.64	8.20	5.07	4.80	8.59	65.07	
1946	12.69	8.07	11.10	4.91	8.36	3.36	5.01	3.76	4.74	4.44	4.13	4.93	75.50	
1947	12.40	2.86	5.53	5.94	4.13	5.02	3.56	6.47	3.21	7.89	6.71	4.31	68.03	
1948	5.88	8.75	11.70	2.50	4.57	4.40	9.60	8.26	3.95	1.19	19.51	7.42	87.73	
1949	9.46	6.72	6.76	8.18	6.12	10.38	8.93	9.00	5.44	10.23	2.59	7.13	90.94	
1950	5.82	8.21	7.39	2.39	5.12	5.00	7.60	10.97	6.26	5.94	2.06	5.98	72.74	
1951	4.00	5.44	7.90	5.57	.98	11.19	7.78	1.61	5.67	4.86	4.24	12.48	71.72	
1952	6.77	5.12	15.93	4.78	3.47	5.16	1.94	5.74	3.58	1.29	5.97	6.88	66.63	
1953	8.83	10.14	5.84	4.34	3.19	7.07	4.57	2.77	4.99	1.09	4.53	10.06	67.42	
1954	12.03	6.53	8.44	5.11	3.57	4.20	6.83	2.94	.40	.82	4.84	10.24	65.95	

R. R. G. 2 for storm separation
Watershed 18 and 9

Sheet 1 of 1 sheets

RI-SE
WATER RELATIONS
Precipitation
Expt. Area Coweeta

US DEPARTMENT OF AGRICULTURE
FOREST SERVICE

PRECIPITATION ON INDIVIDUAL WATERSHEDS

Form 2
File No. 3.132

Watershed 7 Area 1455 acres

Gage Reader C.S. Recorded by H.K.S. Date Computed by A.C. Date

Rain Gage No (1)	Weight Factor* (2)	Date of Rain Sept. 3 Gage Reading (3)	Sept. 3 Reading x Factor (4)	Sept. 12-15 Gage Reading (5)	Sept. 12-15 Reading x Factor (6)	Sept. 20 Gage Reading (7)	Sept. 20 Reading x Factor (8)	Sept. 24 Gage Reading (9)	Sept. 24 Reading x Factor (10)	Sept. 29 Gage Reading (11)	Sept. 29 Reading x Factor (12)	Sept. 29-30 Gage Reading (13)	Sept. 29-30 Reading x Factor (14)	Oct. 5-8 Gage Reading (15)	Oct. 5-8 Reading x Factor (16)	Gage Reading (17)	Reading x Factor (18)
No.	Pct.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.		
12	19	1.10	0.21	0.12	0.02	1.80	0.34	0.49	0.09	0.35	0.07	5.94	1.13	0.88	0.17		
18	19	1.21	0.23	0.12	0.02	2.00	0.38	0.57	0.11	0.37	0.07	6.08	1.16	0.73	0.14		
20	11	1.26	0.14	0.25	0.03	1.88	0.21	0.61	0.07	0.44	0.05	5.94	0.65	0.83	0.09		
21	49	1.21	0.59	0.16	0.08	1.85	0.91	0.60	0.29	0.44	0.22	5.90	2.89	0.92	0.45		
25	2	1.11	0.02	0.34	0.01	1.40	0.03	0.56	0.01	0.41	0.01	5.30	0.11	1.15	0.02		
Total (Inches)			1.19		0.16		1.87		0.57		0.42		5.94		0.87		

* Where Thiessen Method is used

Period September 3 to October 8, 1936

Sheet 1 of 1 Sheets

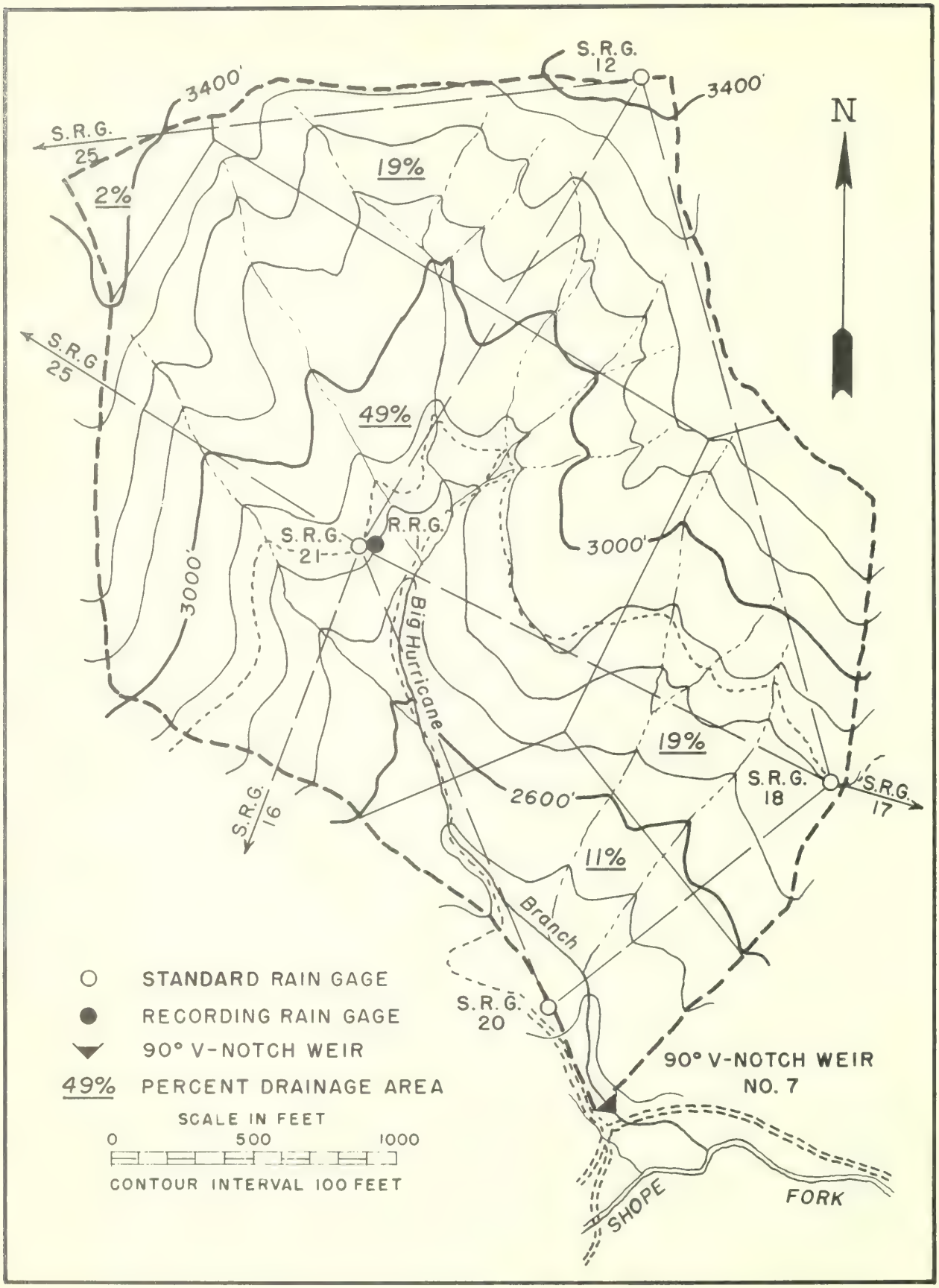

Figure 1.--Rain gage service areas for Watershed 7, a 145.5-acre area.

The standard rain gage (S.R.G.) number and its weight factor are listed in the first and second columns of Form 2. In the remaining 14 columns are recorded individual storms, each storm requiring two columns. The amount of precipitation for each gage is recorded in the first column, the product of the weight factor and the amount of precipitation in the second. The sum of the amounts in the second column is the weighted mean precipitation on the drainage basin in area inches for the individual storms.

This method is ordinarily employed for routine weighted rainfall compilations. However, for special investigations it may be desirable to use other methods such as plotting rainfall isohyetols.

Summary of Weighted Precipitation for Drainage Areas

To complete the summarization of "raw" precipitation data, a summary of the weighted precipitation received on a given watershed is tabulated by months and years. An example of such a tabulation is shown in the Annual Record of Weighted Precipitation below (File No. 3.1321) for Coweeta Watershed No. 18. Note the supplemental data describing elevation, area, recording gage, and standard gages.

RECORDING RAIN GAGE DATA

For most hydrologic work, it is desirable to know not only the total amount of rainfall or recharge but also the manner in which it was received, i.e., the rainfall intensities. Three types of instruments have been used for recording rainfall: the weighing gage, the float gage, and the tipping bucket gage. Only the first of these is commonly used today; however, the method of recording is similar in the first two and this discussion would apply to either type. Rainfall intensities are recorded on the precipitation intensity record, Form 4.

Precipitation Intensity Record--Form 4

On this form is shown a continuous record of rainfall for individual storms as recorded by a single recording rain gage, and also as corrected for the rainfall collected in a standard rain gage, which in each case is installed beside the recording gage. The purpose of this form is to tabulate data for an accurate reproduction of recorded precipitation and to compile precipitation intensity data.

A storm is considered as a period of precipitation separated by at least 6 hours from any other period in which precipitation occurs. The times of beginning and ending of the precipitation are indicated on the recorded chart by the symbols, P.B. and P.E., respectively (fig. 2).

Column 1. Date of rainfall.

Column 2. Time of change in rainfall intensity. The time is read from the recorder chart at the points where significant changes in rainfall rates occur. Such points are called natural breaks.

RI-SE
WATER RELATIONS
Precipitation
Expt. Area Coweeta

File No. 3.1571

U. S. Department of Agriculture
Forest Service
ANNUAL RECORD BY MONTHS OF WEIGHTED
PRECIPITATION ON AN INDIVIDUAL DRAINAGE BASIN

(In inches)

Watershed No. 18

Computed by B.C.
Checked by E.A.J.

Water year	Total	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1935													
1936										7.40	6.79	8.93	5.08
1937	73.20	2.04	12.32	12.60	6.43	3.10	7.89	2.30	5.61	3.97	4.77	2.87	9.30
1938	65.62	2.93	6.86	4.95	2.84	8.97	6.22	6.43	6.94	11.99	3.80	3.53	.16
1939	75.09	11.67	3.33	8.07	16.45	8.20	5.42	3.67	3.44	6.12	6.66	1.15	.91
1940	60.14	.85	4.07	3.39	7.56	5.62	7.74	2.21	7.46	4.34	14.06	.92	1.92
1941	49.73	5.73	5.18	3.61	1.62	5.45	3.50	1.38	3.24	10.54	3.22	3.43	2.83
1942	73.11	4.61	8.41	5.30	6.90	9.81	1.00	9.84	3.34	9.84	4.09	6.39	3.58
1943	78.80	2.65	13.04	7.05	5.16	9.39	6.03	4.16	6.48	11.75	5.06	5.32	2.71
1944	68.14	2.46	4.41	4.56	12.19	12.49	6.75	4.63	1.45	3.89	6.52	7.64	1.15
1945	65.72	5.94	7.50	2.60	8.36	5.78	8.45	3.24	3.06	3.54	3.68	8.42	5.15
1946	79.49	4.87	8.56	12.72	8.03	11.06	4.83	8.44	3.18	4.96	3.54	4.84	4.46
1947	66.05	4.22	5.01	12.33	2.84	5.57	5.83	4.09	5.02	3.72	6.33	3.22	7.87
1948	71.46	6.68	4.31	5.83	8.87	11.54	2.42	4.57	4.35	9.59	8.16	3.97	1.17
1949	107.24	19.15	7.41	9.58	6.81	6.64	8.09	6.02	10.37	8.58	8.91	5.44	10.24
1950	73.91	2.56	7.20	5.97	8.17	7.32	2.40	4.95	4.87	7.49	10.79	6.08	6.11
1951	62.09	2.07	5.78	3.98	5.35	7.77	5.48	.97	11.10	7.36	1.53	5.76	4.94
1952	70.15	4.20	12.66	7.06	5.09	15.60	4.75	3.43	5.02	1.89	5.61	3.53	1.31
1953	65.34	5.97	6.90	8.86	10.11	5.80	4.34	3.08	6.98	4.45	2.85	4.92	1.08
1954	70.19	4.47	9.95	12.19	6.44	12.70	5.09	3.58	4.78	6.89	2.86	.39	.85

Watershed Data:
Max. elevation 3258 ft.
Min. elevation 2382 ft.
Mid. elevation 2703 ft.
Area 30.84 acres

RRG for storm separation 2
Standard rain gages 39, 68

Sheet 1 of 1 sheets

RI-SE
WATER RELATIONS
Precipitation

U S DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Form 4
File No 3.133

PRECIPITATION INTENSITY RECORD

Rain Gage No 1, Type Recording Float
1 Inch on Chart = 1 In. Precip. 80 Min. Time
Time and Date of Storm Sept. 29-30, 19 36
(Circle One (EST.) CST, MST, PST)
Elevation: (M S L) 2875 Feet

Experimental Area Coweeta
Watershed 7 145.5 A
Lat ___ Long ___
Sec ___, Tp ___, Range ___
Total Precipitation 5.94 inches

Date 1936 (1)	Time Hr Min (2)	Time Interval Min (3)	Depth Recorded In (4)	Increment Recorded In (5)	Increment Corrected In (6)	Rate per Hour Inches per Hr (7)	Remarks (8)
Sept.29	1710		.00	.00			P.B. 1710
	1715	5	.07	.07	.07	0.84	
	1725	10	.27	.20	.20	1.20	
	1740	15	.31	.04	.04	0.16	
	1830	50	.32	.01	.01	0.01	
	1850	20	.36	.04	.04	0.12	
	2020	90	.69	.33	.33	0.22	
	2050	30	.76	.07	.07	0.14	
	2100	10	.92	.16	.16	0.96	
	2105	5	1.07	.15	.15	1.80	
	2120	15	1.49	.42	.41	1.64	
	2130	10	1.72	.23	.23	1.38	
	2145	15	1.87	.15	.15	0.60	
	2150	5	2.05	.18	.18	2.16	
	2155	5	2.27	.22	.22	2.64	
	2200	5	2.35	.08	.08	0.96	
	2240	40	2.63	.28	.28	0.42	
	2310	30	2.93	.30	.30	0.60	
	2320	10	3.20	.27	.27	1.62	
	2340	20	3.50	.30	.30	0.90	
	2350	10	3.87	.37	.37	2.22	
	2355	5	4.12	.25	.25	3.00	
	2400	5	4.40	.28	.28	3.36	
Sept.30	0030	30	4.57	.17	.17	0.34	
	0100	30	4.66	.09	.09	0.18	
	0200	60	4.80	.14	.14	0.14	
	0220	20	4.90	.10	.10	0.30	
	0245	25	5.22	.32	.32	0.77	
	0325	40	5.47	.25	.25	0.38	
	0340	15	5.68	.21	.21	0.84	
	0350	10	5.71	.03	.03	0.18	
	0410	20	5.72	.01	.01	0.03	
	0420	10	5.89	.17	.17	1.02	
	0430	10	5.94	.05	.05	0.30	
	0600	90	6.02	.08	.08	0.05	P.E. 0600
Totals							

Correction Factor = Mean Basin Precipitation / Recording Rain Gage Precipitation or S.R.G. 5.94 / 6.02 = .987 Storm Class ___

Maximum Depth and Intensity for Given Time Intervals

Duration Min	2	5	10	15	20	30	60	120	240	6 Hrs	12 Hrs.
Depth in Inches		0.28	0.52	0.71	0.88	1.04	1.53	2.00	3.75	4.41	5.88
Intensity In./Hr		3.36	3.12	2.84	2.63	2.09	1.53	1.00	0.94	0.74	0.49

Tabulated by HKS Date June 1938 Checked by K.A.M. Date June 1938
Computed by HKS Date June 1938 Checked by K.A.M. Date June 1938

Period of Record 1710 Sept.29 to 0410 Sept.30,1936

Sheet 1 of 1 Sheets

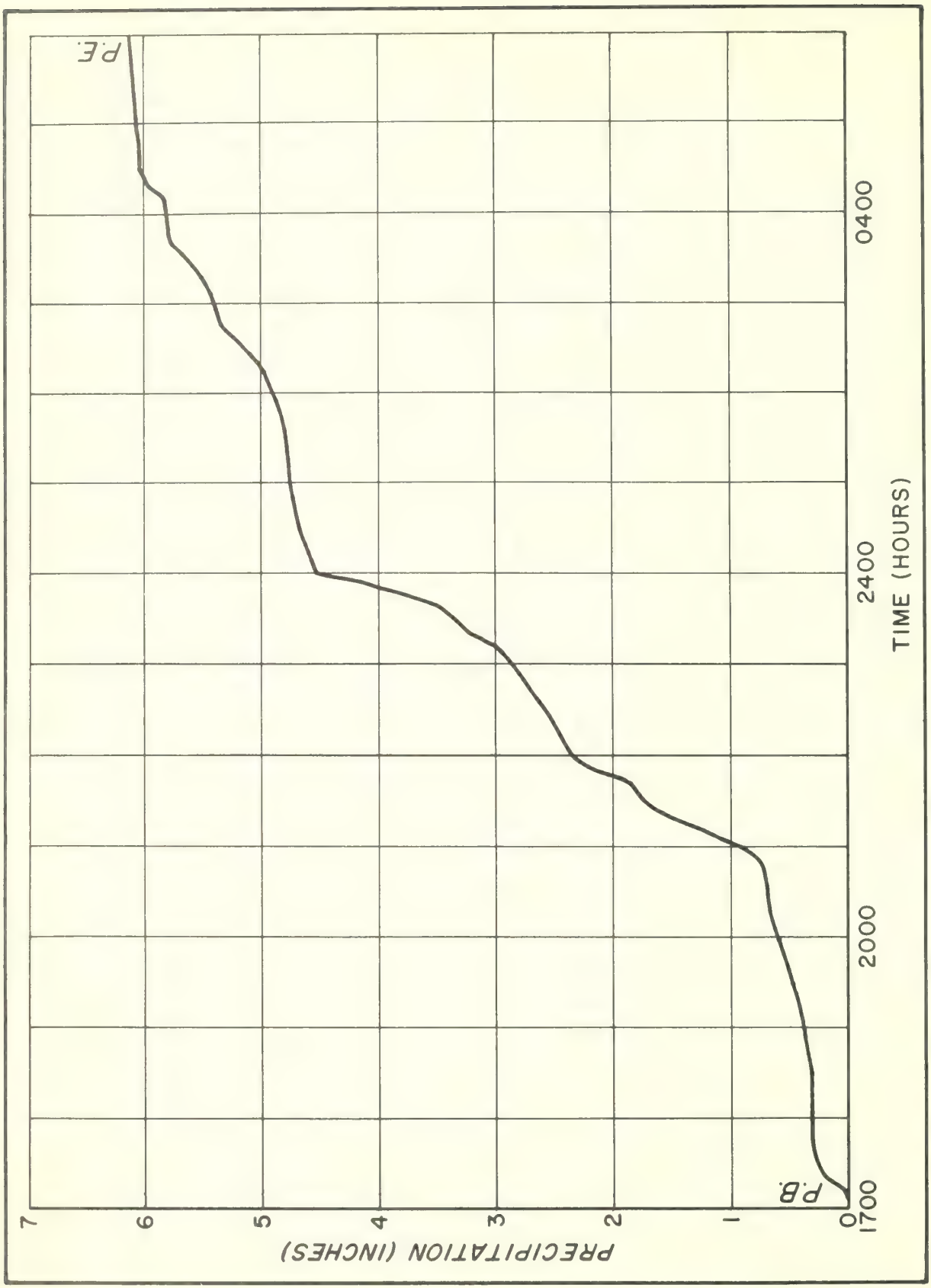

Figure 2.--Mass rainfall curve for storm of September 29-30, 1936, from recording rain gage 1 on Watershed 7.

Column 3. Time intervals in minutes between natural breaks in rainfall intensity are entered here. Intervals are always read to the smallest time interval that can be determined with a reasonable degree of accuracy from the individual recorder chart.

Column 4. Accumulated rainfall or cumulative depths in inches at the end of each time interval are recorded in column 4.

Column 5. The actual increments between intervals are entered here. The first line of the first sheet of a record will be blank.

Column 6. The entries in column 5 are corrected to the standard rain gage catch and entered in column 6. Corrections may be necessary because of instrumental errors, such as pen reversal, base line errors, etc. Depending upon the objective, the mean basin precipitation (weighted area precipitation) may also be used for this correction. The correction factor, as noted on the bottom of the form, is the standard rain gage reading (control rain gage) or the mean basin precipitation value divided by the total recorded rainfall. Figures in column 5 multiplied by this correction factor are the corrected values shown in column 6.

Column 7. The increments of column 6 are converted into rainfall rates in inches per hour for the time interval.

$$\frac{\text{col. 6} \times 60}{\text{col. 3}} = \text{column 7}$$

Column 8. Notes of beginning and ending of rainfall (P.B. and P.E.) are recorded opposite times shown in column 2. This column is also used for pertinent remarks about the storm or comments concerning the computations. At the bottom of the form, space is provided for recording on the proper lines the figures used in determining the correction factor. The blank provided for storm class may be used for special storm studies. It is not used for routine compilations. The maximum rainfall depths and intensities in inches per hour are recorded for selected rainfall durations in minutes. These rates are obtained by scanning the chart to get the combination producing the maximum rate for each time interval. Note that they are taken directly from the chart and not from the recorded depths. With a little experience these rates can be taken readily from the chart with a template and/or a pair of dividers. Blanks are also provided for dating and initialing the tabulations and checking. In addition, the period of record (dates and times) should be entered at the bottom of the page. Even though no precipitation occurs on some dates, the times and dates from one chart to the next should be continuous to show that no storms have been missed or skipped.

Weighted Rainfall Intensity Records

On larger drainage areas or where intensive sampling is desired on small areas, more than one recording rain gage may be used to service the area. In this case it may be desirable to weight the rainfall intensity data. This may be done by again applying the Horton-Thiessen mean method as outlined previously.

TILTED GAGES

For special studies located in areas of rugged topography with varied wind currents and exposures, it is sometimes desirable to compare precipitation caught in rain gages having orifices set parallel to the slope with the conventional vertically placed gages. Because of differences in the area of the receiver or orifice of the tilted gage exposed to rainfall, it is necessary to correct the tilted-gage values to the equivalent horizontal-gage reading in order to make comparisons between the two settings. The procedure used at the Coweeta Hydrologic Laboratory for making such corrections is given below.

The amount of rainfall in the conventionally placed gage is measured and emptied. Then the volume of rain in the tilted gage is poured into the 2-inch receiver of the standard gage and measured. To correct the latter value, the measured depth in inches is divided by the cosine of the slope angle or the angle of tilt of the tilted gage. Some sample computations are as follows:

Gage number	Field readings		Cosine θ correction factor	Corrected tilted-gage reading	Deviation of tilted gage from vertical gage catch	
	Vertical gage	Tilted gage				
	Inches	Inches		Inches	Inches	Percent
2	3.70	3.53	.9363	3.77	+.07	2
61	3.93	3.36	.8772	3.83	-.10	3
64	4.33	3.58	.8456	4.13	-.20	5
70	4.10	3.35	.7727	4.33	+.23	6

RUNOFF

The term runoff as used in this paper refers to total discharge and is synonymous with streamflow. Runoff from small drainage areas is ordinarily gaged by measuring the depth of water flowing through a weir. The rise and fall of the water in the weir is recorded on a chart, and by the application of rating tables the runoff may be converted to rates and volumes. Rating table values are usually given in cubic feet per second. The various units in which water is measured and some of the conversion factors that may be applied are given at the beginning and end of this paper.

RECORD OF RUNOFF--FORM 6

This form is used in computing a continuous record of runoff for an individual drainage basin. Data are broken down into time intervals of such lengths that the records may be used in the analysis of water yield, storm flow, baseflow accretion and depletion, infiltration, and storage or detention. The procedure outlined here is designed to give total water yield. For determining total storm runoff, it is necessary to affix the time of the start and the time of the end of storm runoff and, further, to deduct the base flow or ground water flow. The procedures used in computing the data, however, are similar to those used in computing total water yield.

Form 6 is designed to permit accurate reproduction of the stream hydrograph as well as to give total water yield. To keep the error small, the time intervals are limited by two factors: (1) the curvature of the stage hydrograph and (2) the curvature of the stage-discharge relation. Both factors produce a cumulative error, the net result usually being over-estimated discharges. The error due to curvature of the stage hydrograph is eliminated by breaking the hydrograph into segments which do not have appreciable curvature, while the error due to curvature of the stage-discharge relation is reduced by breaking the hydrograph into short intervals.

Figure 3 illustrates some of the features explained below in connection with the execution of Form 6.

Top of form. The station designation, date of rating table applied, and integrator setting should be indicated in the proper blanks. A complete station description, including name, location, size, elevation, gage type, type of recording instrument, etc., should be available for each station.

Column 1. The date is inserted here.

Column 2. The time of day at which the hydrograph is broken is recorded in hours and minutes to the nearest number of minutes that can be read accurately from the given chart (e.g., 2, 5, 10 or 15). A break in the hydrograph is always made at midnight, at all peaks, at all troughs, and at definite changes in the slope of the hydrograph. In listing the times, a line is left blank after midnight and, where the time of beginning and ending of stormflow is indicated, lines are left blank preceding the start of stormflow and after the end of stormflow.

Column 3. The time intervals in minutes between successive breaks (or between the times of column 2) of the hydrograph are tabulated.

Column 4. Gage heights at the breaks of the hydrograph (or at the times shown in column 2) are read from the hydrograph and recorded in column 4.

RI-SE
WATER RELATIONS
Streamflow
Water Yield

U. S. Department of Agriculture
Forest Service

RECORD OF RUNOFF

Form c
File No. 3.2211

Expt. Area COWEETA
Station designation No. 7

Discharge rates from rating table dated: Dec. 1, 1934

Date	Time	Time interval	Gage height	Discharge rate: For gage height	Discharge rate: Average for interval		Runoff from area: For interval		Runoff from area: Accumulated			Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
1936	Hr. min.	Min.	Ft.	C.f.s.	C.f.s.	In./hr.	Cu. ft.	Inches	Cu. ft.	Inches	C.s.m.	
Sept. 28	12:00	720	0.400	0.262	0.262	0.0018	11,318	0.0214	11,318	0.0214		
	2:00p	120	0.390	0.246	0.254	0.0017	1,829	0.0035	13,147	0.0247		
	5:00	180	0.386	0.240	0.243	0.0017	2,624	0.0050	15,771	0.0299		
	9:00	240	0.398	0.259	0.250	0.0017	3,600	0.0068	19,371	0.0367		
	12:00	180	0.400	0.262	0.260	0.0018	2,808	0.0053	22,179	0.0420		
									22,179	0.0420	1.13	Sept. 28 total = 22,179
29	2:00a	120	0.402	0.265	0.264	0.0018	1,901	0.0036	1,901	0.0036		S.R.B. 2:00 a.
	3:00	60	0.438	0.328	0.296	0.0020	1,066	0.0020	1,066	0.0020		
	3:40	40	0.491	0.435	0.382	0.0026	917	0.0017	1,983	0.0038	1.9140	M.P. 3:40 a.
	4:00	20	0.437	0.326	0.380	0.0026	456	0.0009	2,439	0.0046	(0.0030	in./hr.)
	4:30	30	0.455	0.360	0.343	0.0023	617	0.0012	3,056	0.0058		
	6:00	90	0.413	0.284	0.322	0.0022	1,739	0.0033	4,795	0.0091		
	6:20	20	0.428	0.310	0.297	0.0020	356	0.0007	5,151	0.0098		
	6:40	20	0.408	0.275	0.292	0.0020	350	0.0007	5,501	0.0104		
	7:30	50	0.406	0.272	0.274	0.0019	822	0.0016	6,323	0.0120	1.4051	S.R.E. 7:30 a. Total stormflow 6,323
	9:00	90	0.383	0.236	0.254	0.0017	1,372	0.0026	1,372	0.0026		
	12:00	180	0.370	0.216	0.226	0.0015	2,441	0.0046	3,813	0.0072		
	2:00p	120	0.368	0.213	0.214	0.0015	1,541	0.0029	5,354	0.0101		
	5:30	210	0.370	0.216	0.214	0.0015	2,696	0.0051	8,050	0.0152		S.R.B. 5:30 p.
	5:40p	10	0.400	0.262	0.239	0.0016	143	0.0003	143	0.0002		
	6:00	20	0.450	0.351	0.306	0.0021	367	0.0007	510	0.0010		
	6:20	20	0.477	0.405	0.378	0.0026	454	0.0009	964	0.0018		
	6:40	20	0.500	0.455	0.430	0.0029	516	0.0010	1,480	0.0028		
	7:00	20	0.480	0.411	0.433	0.0030	520	0.0010	2,000	0.0038		
	7:30	30	0.470	0.390	0.400	0.0027	720	0.0014	2,720	0.0052		
	8:00	30	0.488	0.428	0.409	0.0028	736	0.0014	3,456	0.0065		
	8:30	30	0.530	0.525	0.476	0.0032	857	0.0016	4,313	0.0082		
	8:45	15	0.536	0.540	0.532	0.0036	479	0.0009	4,792	0.0091		
	9:00	15	0.600	0.714	0.627	0.0043	564	0.0011	5,356	0.0101		
	9:10	10	0.780	1.364	1.039	0.0071	623	0.0012	5,979	0.0113		
	9:20	10	0.852	1.697	1.530	0.0104	918	0.0017	6,897	0.0131		

Tabulated by H.K.S. Date May 1938 Checked by K.A.M. Date May 1938
Computed by I.W. Date May 1939 Checked by A.C. Date May 1939

Sheet 1 of 3 sheets

RI-SE
WATER RELATIONS
Streamflow
Water Yield

U. S. Department of Agriculture
Forest Service

RECORD OF RUNOFF

Form 6
File No. 3.2211

Expt. Area COWEETA
Station designation No. 7

Discharge rates from rating table dated: Dec. 1, 1934

Date	Time	Time interval	Gage height	Discharge rate: For gage height	Discharge rate: Average for interval		Runoff from area: For interval		Runoff from area: Accumulated			Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
1936	Hr. min.	Min.	Ft.	C.f.s.	C.f.s.	In./hr.	Cu. ft.	Inches	Cu. ft.	Inches	C.s.m.	
Sept 29	9:40	20	1.000	2.520	2.108	0.0144	2,530	0.0048	9,427	0.0179		
	10:00	20	1.118	3.319	2.920	0.0199	3,504	0.0066	12,931	0.0245		P. 10.00 p.
	10:30	30	1.060	2.910	3.114	0.0212	5,605	0.0106	18,536	0.0351		
	11:00	30	0.948	2.209	2.560	0.0175	4,608	0.0087	23,144	0.0438		T. 11:00 p.
	11:20	20	1.020	2.646	2.428	0.0166	2,914	0.0055	26,058	0.0494		
	11:40	20	1.100	3.189	2.918	0.0199	3,502	0.0066	29,560	0.0560		
	12:00	20	1.343	5.221	4.205	0.0287	5,046	0.0096	34,606	0.0655		
									50,880	0.0964	2.59	Total Sept. 29 = 50,880
30	12:10a	10	1.534	7.251	6.236	0.0425	3,742	0.0071	38,348	0.0726	31.9044	M.P. 12:10 a.
	12:30	20	1.401	5.796	6.524	0.0445	7,829	0.0148	46,177	0.0875	(0.0495	in./hr.)
	1:00a	30	1.200	3.953	4.874	0.0332	8,773	0.0166	54,950	0.1041		
	2:00	60	0.980	2.397	3.175	0.0217	11,430	0.0216	66,380	0.1257		
	2:20	20	0.970	2.337	2.367	0.0161	2,840	0.0054	69,220	0.1311		T. 2:20 a.
	3:00	40	1.100	3.189	2.763	0.0188	6,631	0.0126	75,851	0.1437		
	3:10	10	1.108	3.247	3.218	0.0219	1,931	0.0037	77,782	0.1473		
	3:30	20	1.090	3.118	3.182	0.0217	3,818	0.0072	81,600	0.1546		
	3:50	20	1.172	3.730	3.424	0.0234	4,109	0.0078	85,709	0.1623		P. 3:50 a.
	4:10	20	1.140	3.483	3.606	0.0246	4,327	0.0082	90,036	0.1705		
	4:30	20	1.168	3.698	3.590	0.0245	4,308	0.0082	94,344	0.1787		
	5:00	30	1.120	3.334	3.516	0.0240	6,329	0.0120	100,673	0.1907		
	6:00	60	1.021	2.653	2.994	0.0204	10,778	0.0204	111,451	0.2111		
	7:00	60	0.925	2.079	2.366	0.0161	8,518	0.0161	119,969	0.2272		
	8:00	60	0.860	1.736	1.908	0.0130	6,869	0.0130	126,838	0.2402		
	9:00	60	0.807	1.484	1.610	0.0110	5,796	0.0110	132,634	0.2512		
	10:00	60	0.764	1.296	1.390	0.0095	5,004	0.0095	137,638	0.2607		
	12:00	120	0.710	1.081	1.188	0.0081	8,554	0.0162	146,192	0.2769		
	2:00p	120	0.668	0.930	1.006	0.0069	7,243	0.0137	153,435	0.2906		
	5:00	180	0.612	0.749	0.840	0.0057	9,072	0.0172	162,507	0.3078		
	8:00	180	0.576	0.645	0.697	0.0048	7,528	0.0143	170,035	0.3220		
	12:00	240	0.548	0.570	0.608	0.0041	8,755	0.0166	178,790	0.3386		
									144,184	0.2731	7.34	Total Sept. 30 = 144,184

Tabulated by H.K.S. Date May 1938 Checked by K.A.M. Date May 1938
Computed by I.W. Date May 1939 Checked by A.C. Date May 1939

RI-SF
WATER RELATIONS
Streamflow
Water Yield

U. S. Department of Agriculture
Forest Service

RECORD OF RUNOFF

Form 6
File No. 3.2211

Expt. Area COWEETA
Station designation No. 7

Discharge rates from rating table dated: Dec. 1, 1934

Date	Time	Time interval	Gage height	Discharge rate: For gage height	Discharge rate: Average for interval		Runoff from area: For interval		Runoff from area: Accumulated			Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
1936	Hr. min.	Min.	Ft.	C.f.s.	C.f.s.	In./hr.	Cu. ft.	Inches	Cu. ft.	Inches	C.s.m.	
Oct. 1	6:00a	360	0.516	0.492	0.531	0.0036	11,470	0.0217	190,260	0.3604		
	12:00	360	0.493	0.439	0.466	0.0032	10,066	0.0191	200,326	0.3794		
	12:00	720	0.465	0.380	0.410	0.0028	17,712	0.0335	218,038	0.4130		S.R.E. 1200 mdt.
									218,038	0.4130	5.5394	Stormflow = 218,038
									39,248	0.0743	2.00	Total Oct. 1 = 39,248
2	11:00a	660	0.450	0.351	0.366	0.0025	14,494	0.0275	14,494	0.0274		
	3:00p	240	0.439	0.330	0.340	0.0023	4,896	0.0093	19,390	0.0367		
	12:00	540	0.438	0.328	0.329	0.0022	10,660	0.0202	30,050	0.0569		
									30,050	0.0569	1.53	Total Oct. 2 = 30,050
3	10:00a	600	0.431	0.315	0.322	0.0022	11,592	0.0220	11,592	0.0220		
	3:00p	300	0.420	0.296	0.306	0.0021	5,508	0.0104	17,100	0.0324		
	12:00	540	0.422	0.299	0.298	0.0020	9,655	0.0183	26,755	0.0507		
									26,755	0.0507	1.36	Total Oct. 3 = 26,755
												Total for 5-day period 313,296

Tabulated by H.K.S. Date May 1938 Checked by K.A.M. Date May 1938
Computed by I.W. Date May 1939 Checked by A.C. Date May 1939

Sheet 3 of 3 sheets

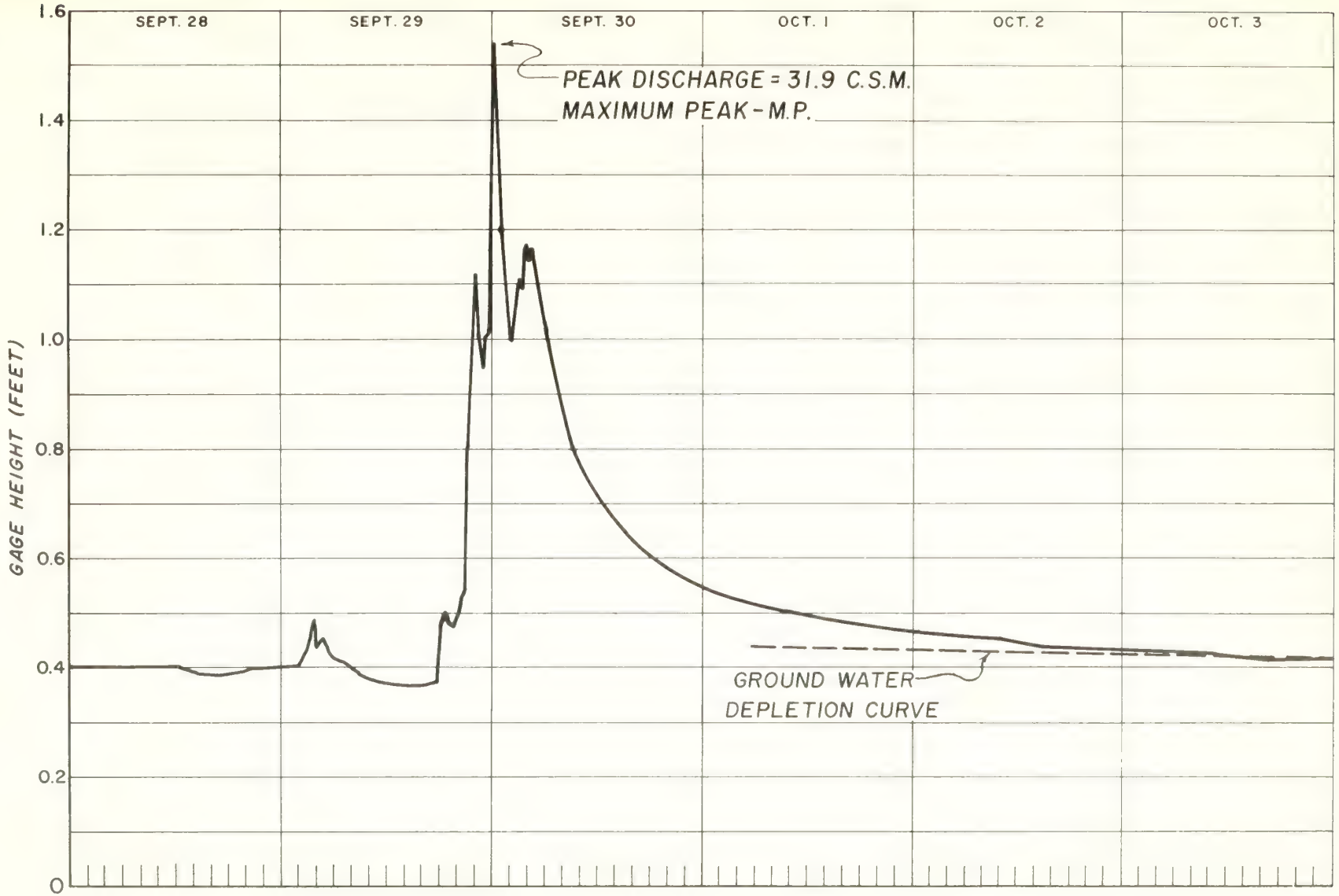

Figure 3.--A stage hydrograph for the period September 28 to October 3, 1936, from the 90° V-notch weir on Watershed 7.

Column 5. Discharge rates in cubic feet per second for the gage heights are obtained from the stage-discharge (rating) table for the measuring device [2/] employed, and are inserted in column 5.

Column 6. In column 6 are recorded the average discharge rates in cubic feet per second for the time intervals of column 3. These values are obtained by averaging the successive discharge rates of column 5.

Column 7. The discharge rates of column 6 are converted into inches per hour and tabulated in column 7. These values are obtained by multiplying each of the column 6 figures by the conversion factor shown in the heading of form 6. The conversion factor equals

$$\frac{3600 \times 12}{43560 \times \text{drainage area in acres}}$$

Column 8. Column 8 is used to record the runoff from the drainage basin in cubic feet for the time intervals of column 3. Column 8 equals column 3 x column 6 x 60 seconds.

Column 9. The runoff from the drainage basin in inches for the time intervals of column 3 are listed in column 9.

$$\text{Column 9} = \text{column 7} \times \frac{\text{column 3}}{60}$$

$$\text{or} \quad \frac{\text{column 8} \times 12}{\text{drainage area in acres} \times 43560}$$

Column 10. Column 10 shows the accumulated runoff from the drainage basin in cubic feet. It is obtained by adding the values in column 8 and recording the sum opposite the last figure added. Thus, any value in column 10 represents the total runoff from the starting point to the time shown in column 2. In order to show total runoff by days, starting points for accumulated runoff are always taken at midnight. For storm studies, starting points are also taken at the beginning of storm runoff and stopped at the end of the stormflow. Accumulated runoff during a storm is carried beyond midnight to the end of storm flow, in which case the daily total runoff is recorded on the blank line which follows each midnight. Total storm runoff is similarly recorded.

Column 11. The values in column 10 are converted into inches and recorded in column 11.

$$\text{Column 11} = \frac{\text{Column 10} \times 12}{\text{drainage area in acres} \times 43560}$$

2/ For the 90-degree V-notch weir used in the following example see H. W. King, Handbook of Hydraulics, table 44, pp. 4-59 to 4-62, 4th Edition, McGraw Hill, New York, 1954.

Column 12. Column 12 is used for showing the mean daily discharge in cubic feet per second per square mile (c.s.m.). 3/

$$\text{Column 12} = \frac{\text{column 10 (daily total) x 640}}{\text{drainage area in acres x 86400}}$$

The maximum peak discharge rate in cubic feet per second is converted to cubic feet per second per square mile and inches per hour and these are also recorded in column 12.

Column 13. The remarks inserted in column 13 must include the following:

Peak (P) noted at each point where the hydrograph changes from a rising to a falling stage.

Maximum Peak (M.P.) the highest peak of the entire storm.

Trough (T) noted at each point where the hydrograph changes from a falling to a rising stage.

For special storm studies, the time storm (or surface) runoff begins (S.R.B.) and the time storm (or surface) runoff ends (S.R.E.) are also noted.

Column 13 is also used for recording any observations, remarks, or notes pertaining to the chart recorded or to any of the computations required in executing the form.

RUNOFF SUMMARIES

Drainage Discharge Data--Forms 7 and 7a

These forms are used for summarizing the discharge or runoff data from an individual drainage basin. Form 7 is for the growing season, May 1 to October 31, and form 7a is for the dormant season, November 1 to April 30. The mean discharge in c.f.s. per square mile (c.s.m.) is obtained from column 12, form 6, and tabulated for each day. These data are plotted as a continuous streamflow hydrograph (fig. 4) which in turn is used as a guide in estimating missing records and as a basis for streamflow analyses. Note on form 7 the line in column 2, May, from May 13 through May 15 and the accompanying footnote. This indicates that the record for this period has been estimated. If for some reason data are missing or lost, as for instance when the weir is being cleaned or repaired, the record may be estimated from the record of an adjacent watershed.

3/ The heading of this column is left blank so that conversions or data required for special studies may be inserted.

RI-SE
WATER RELATIONS
Streamflow
Water Yield
Expt. Area Coweeta

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Form 7
File No. 3.2212

WATERSHED DISCHARGE DATA

Mean Discharge in C.s.m. by Days, Months, and Season

Computed by H.K.S.
Checked by K.A.M.

Watershed 7 Area 145.5 A.

Discharge by Months for Growing Season 19 36

Date (1)	May (2)	June (3)	July (4)	Aug. (5)	Sept. (6)	Oct. (7)	(8)	(9)	(10)
1	5.29	2.61	1.76	1.87	1.06	2.03			
2	5.14	2.56	3.04	1.65	1.06	1.53			
3	5.28	2.51	1.97	1.50	1.56	1.36			
4	4.88	2.85	2.20	1.40	1.17	1.27			
5	4.68	2.54	1.76	1.36	1.08	1.23			
6	4.73	2.49	1.73	1.31	1.06	1.26			
7	4.48	2.44	1.67	1.35	1.04	1.34			
8	4.33	2.48	1.63	1.30	1.02	1.52			
9	4.22	2.43	1.67	1.27	1.05	1.70			
10	4.13	2.70	1.64	1.30	1.05	1.83			
11	4.81	2.48	1.68	1.23	1.01	1.49			
12	4.87	2.84	2.56	1.19	1.02	1.38			
13	1/4.24	2.47	2.03	1.18	0.98	1.34			
14	1/4.07	2.29	1.78	1.17	0.96	1.28			
15	1/3.94	2.23	1.68	1.16	0.99	1.26			
16	3.83	2.13	1.64	1.14	0.95	1.63			
17	3.72	2.06	1.94	1.17	0.95	1.35			
18	3.54	2.10	1.67	1.09	0.92	1.28			
19	3.59	2.07	1.58	1.35	1.03	1.24			
20	3.45	2.06	1.56	1.14	1.70	1.22			
21	3.45	2.01	1.65	1.10	1.08	1.20			
22	3.25	1.99	1.51	1.07	0.98	1.21			
23	3.14	2.00	1.49	1.12	0.95	1.64			
24	3.11	1.96	1.50	1.45	1.12	1.30			
25	3.03	1.87	1.47	1.23	1.00	1.26			
26	2.96	1.84	1.42	1.15	1.00	1.34			
27*	3.06	1.76	1.38	1.11	1.04	1.25			
28	2.89	1.73	1.36	1.27	1.13	1.22			
29	2.80	1.69	1.37	1.34	2.59	1.20			
30	2.75	1.65	1.82	1.15	7.44	1.17			
31	2.67		1.81	1.09		1.15			
Total	120.33	66.84	53.97	39.21	39.99	42.48			
Mean	3.88	2.23	1.74	1.26	1.33	1.37			
Area Inches	4.48	2.49	2.01	1.46	1.49	1.58			
Precip Inches	2.62	4.02	7.87	4.30	10.14	4.67			
Runoff % Precip	171.0	61.9	25.5	34.0	14.7	33.8			

	For 6 Months Ending Oct. 31	For 12 Months Ending Oct. 31
Total	362.82	1150.34
Mean	1.97	3.14
Area Inches	13.49	42.78
Precip in Inches	33.62	83.03
Runoff as % of Precip	40.1	51.5

Period May 1, 1936 to October 31, 1936 Sheet 1 of 2 Sheets

1/ Weir being repaired--flow estimated from an adjacent watershed.

RI-SE
WATER RELATIONS
Streamflow
Water Yield
Expt. Area Coweeta

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Form 7a
File No. 3.2212

WATERSHED DISCHARGE DATA

Mean Discharge in C.s.m. by Days, Months, and Season

Watershed 7 Area 145.5 A.

Computed by H.K.S.
Checked by K.A.M.

Discharge by Months for Dormant Season 19 36-1937

Date	Nov.	Dec.	Jan.	Feb.	March	April			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	1.15	1.11	5.69	5.44	4.53	3.23			
2	1.14	1.19	9.47	5.20	4.42	3.20			
3	1.15	1.48	11.75	5.05	4.40	3.19			
4	1.41	1.18	7.55	4.92	4.40	3.56			
5	1.23	1.14	6.62	4.80	4.28	4.68			
6	1.26	1.84	6.08	4.62	4.16	4.43			
7	1.22	3.19	5.53	4.93	4.16	3.97			
8	1.22	1.88	5.11	4.93	4.32	4.67			
9	1.16	1.58	4.74	7.19	4.07	4.45			
10	1.14	1.48	4.45	6.41	4.00	4.10			
11	1.14	1.58	4.40	5.56	3.93	3.91			
12	1.40	1.44	4.35	5.20	3.82	3.72			
13	1.15	1.38	4.24	5.14	3.80	3.62			
14	1.12	1.38	4.09	5.08	3.88	3.60			
15	1.12	1.39	5.02	4.90	4.10	3.58			
16	1.10	1.41	4.52	4.85	3.94	3.35			
17	1.12	1.35	4.71	4.59	3.85	3.22			
18	1.12	1.55	6.07	4.59	3.83	3.15			
19	1.10	5.03	7.53	4.43	3.69	3.14			
20	1.07	3.58	6.91	5.69	3.66	3.11			
21	1.05	2.62	6.23	6.03	3.58	3.30			
22	1.06	2.25	5.74	5.60	3.47	3.29			
23	1.06	2.03	5.45	5.26	3.43	3.23			
24	1.07	1.92	5.40	5.11	3.77	3.69			
25	1.06	1.83	6.34	4.90	3.82	5.89			
26	1.05	1.76	5.78	4.74	3.61	4.42			
27*	1.02	1.75	5.44	4.66	3.53	3.97			
28	1.03	1.92	5.61	4.64	3.39	3.89			
29	1.03	2.69	5.27		3.32	4.74			
30	1.02	2.83	5.08		3.27	4.34			
31		8.59	5.64		3.23				
Total	33.97	66.35	180.81	144.46	119.66	114.64			
Mean	1.13	2.14	5.83	5.16	3.86	3.82			
Area Inches	1.26	2.47	6.72	5.37	4.45	4.26			
Precip Inches	1.60	10.62	12.27	5.63	2.81	7.33			
Runoff % Precip	78.8	23.3	54.8	95.4	158.4	58.1			

	For 6 Months Ending April 30	For 12 Months Ending April 30
Total	659.89	1022.71
Mean	3.65	2.80
Area Inches	24.54	28.03
Precip. in Inches	40.26	73.88
Runoff as % of Precip.	61.0	51.5

Period November 1, 1936 to April 30, 1937

Sheet 2 of 2 Sheets

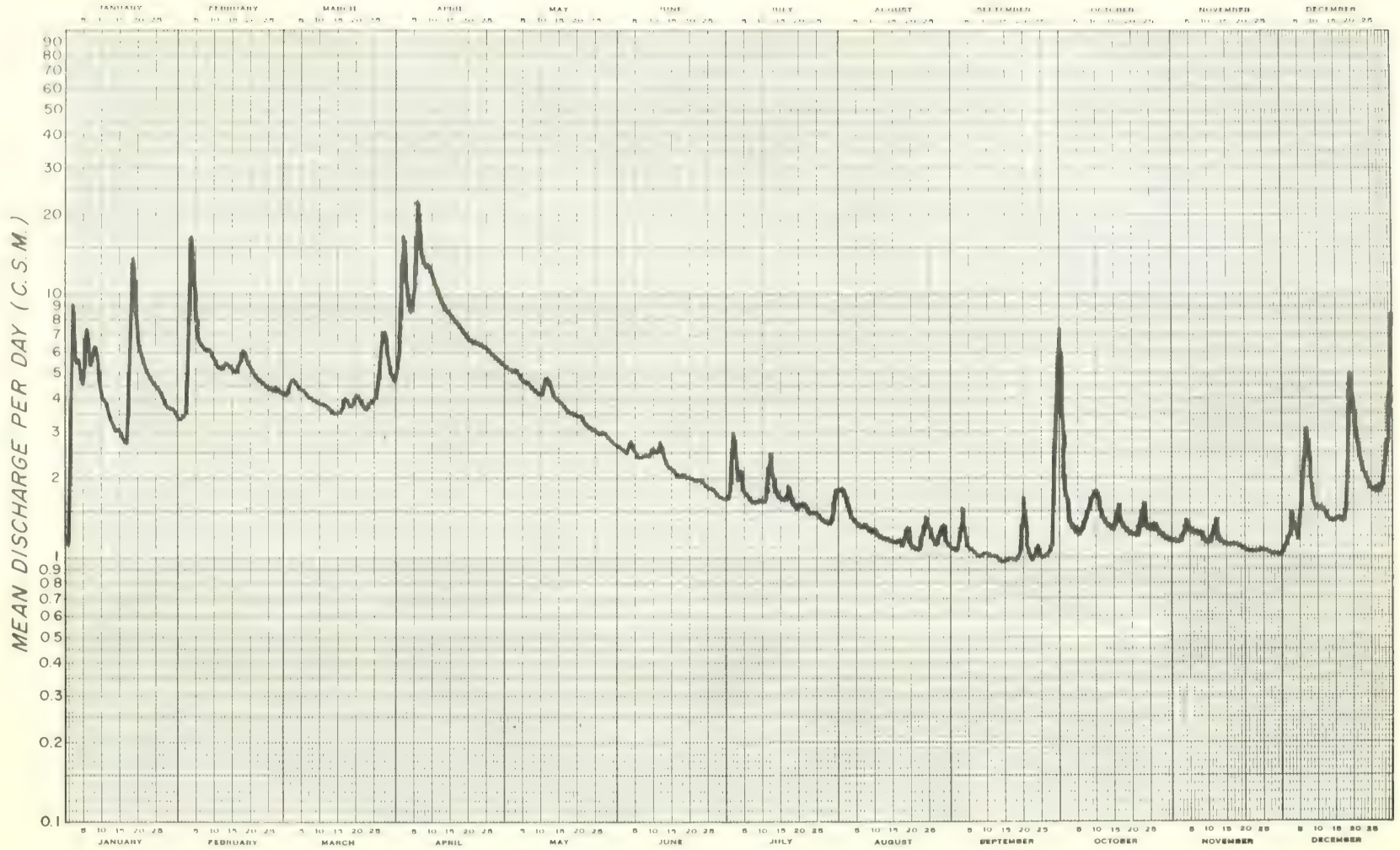

Figure 4.--Stream hydrograph of mean daily discharge, Watershed 7, for 1936.

At the bottom of the page the data are summarized by months, seasons, and years as follows:

Total: The summation of the daily discharges for the month, season and year. This number has no significance but is used in the computations which follow.

Mean: Mean daily c.s.m. for the period =

$$\frac{\text{total of mean daily discharge}}{\text{number of days}}$$

Area inches: The volume of runoff expressed as inches depth on the drainage area.

$$\frac{\text{(Total of mean daily discharge) x 86,400 sec.}}{2,323,200}$$

2,323,200 cubic feet = 1-inch depth on 1 square mile.

Inches precipitation: The weighted mean precipitation on the drainage basin taken from form 2.

$$\text{Runoff as a percent of the precipitation} = \frac{\text{area inches runoff}}{\text{inches precipitation}}$$

Stream Hydrograph and Summary by Hydrologic Years

In compiling runoff data, two other runoff summaries are ordinarily made in addition to the drainage discharge data. The first of these is the actual stream hydrograph for a calendar year (fig. 4), in which the mean daily discharge in c.s.m. is shown graphically by days and months. Periods of high and low flows as well as the hydrologic seasons show up on the stream hydrograph.

The second summary consists of a tabulation of total discharge from a given drainage area by months and years on the basis of hydrologic years, i.e., from November through the following October. An example of this summary is given on the following page.

Maximum and Minimum Flow Tabulations

For various flood control and water yield studies, it is frequently desirable to have a compilation of maximum and/or minimum flows. For other special studies, compilations of all stream rises or all stream flows over a given base may be made. On such compilations, the purpose, date, time of peak, head, flow in c.f.s., c.s.m., and inches per hour and pertinent remarks such as type of storm should be indicated. A tabulation of the annual instantaneous maximum flood peak discharges for Coweeta Watershed No. 18 is shown on page 27.

RI-SE
WATER RELATIONS
Streamflow
Water Yield
Expt. Area Coweeta

File No. 5.22121

U. S. Department of Agriculture
Forest Service
ANNUAL RECORD BY MONTHS OF
RUNOFF DATA
FOR AN INDIVIDUAL DRAINAGE AREA
(Area inches)

Watershed No. 18 Area 30.84 acres

Computed by W.C.
Checked by E.A.J.

Water year	Total	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1935													
1936										1.27	0.94	1.05	1.49
1937	39.07	1.16	3.07	10.03	6.63	4.32	4.14	3.47	2.00	1.26	1.00	.75	1.24
1938	31.23	.91	1.65	2.22	1.96	4.11	5.19	3.12	2.58	3.22	3.31	1.80	1.16
1939	45.09	2.38	1.88	3.12	12.75	9.91	5.37	3.57	2.05	1.53	1.29	.69	.55
1940	21.12	.42	.53	.70	1.72	1.97	3.90	2.95	2.18	1.45	2.24	1.83	1.23
1941	17.84	1.36	1.47	2.09	1.67	2.29	2.67	1.74	1.08	1.65	.83	.54	.45
1942	31.70	.59	1.58	2.06	4.29	6.73	3.89	4.10	2.44	2.09	1.48	1.31	1.14
1943	44.66	1.10	4.73	5.79	6.30	6.09	5.10	3.76	2.35	3.61	2.78	1.78	1.27
1944	37.13	1.14	1.14	2.17	4.87	9.17	7.92	4.47	2.16	1.34	1.08	.98	.69
1945	26.26	.85	1.30	2.28	3.28	4.06	4.64	4.04	1.97	1.23	.93	.99	.69
1946	44.43	.83	2.05	7.67	7.28	7.65	5.12	5.62	3.01	2.09	1.20	.99	.92
1947	30.68	.96	1.21	5.86	3.59	4.07	4.94	3.50	2.17	1.41	1.14	.79	1.04
1948	40.97	1.80	2.14	2.66	6.91	7.86	6.73	3.36	1.71	2.20	3.02	1.52	1.06
1949	65.38	5.49	6.37	8.64	6.99	5.30	5.88	5.89	5.48	4.69	3.55	3.79	3.31
1950	46.42	4.08	4.36	5.23	5.56	7.65	4.46	2.98	2.24	1.69	1.68	4.05	2.44
1951	32.47	1.85	3.24	2.69	3.18	4.54	5.17	3.26	2.85	2.25	1.31	1.15	.98
1952	46.28	1.52	5.97	5.27	5.59	13.15	6.28	3.38	2.08	.91	.91	.69	.53
1953	29.38	.72	1.23	3.27	6.18	5.61	3.74	3.26	1.98	1.39	.86	.65	.49
1954	35.90	.62	2.12	6.37	4.26	6.26	5.88	4.00	2.57	1.81	1.07	.54	.40

Watershed data:
Max. elevation 3258 ft.
Min. elevation 2382 ft.
Mid. elevation 2703 ft.

Control:
120° V-notch blade

RI-SE
WATER RELATIONS
Streamflow
Expt. Area Coweeta

U. S. Department of Agriculture
Forest Service
ANNUAL INSTANTANEOUS MAXIMUM FLOW
DISCHARGE FOR AN INDIVIDUAL DRAINAGE AREA

File No. 3.2102

Watershed No. 18 Area 30.54 acres

Computed by E.A.J.
Checked by J.L.K.

Calendar year	Date	Time	Head	Discharge		Remarks
			Feet	C.f.s.	C.s.m.	
1936	9-30	0020	0.802	2.565	53.22	Records begin
1937	4-25	0030	.584	1.187	24.63	June 3, 1936
1938	11-5	0250	1.130	5.976	124.00	
1939	2-3	1230	1.035	4.819	99.99	
1940	8-29	2220	.795	2.526	52.41	
1941	7-5	1045	.464	.749	15.55	
1942	5-20	1010	.744	2.154	44.70	
1943	7-5	1840	.616	1.352	28.05	
1944	3-27	0150	.573	1.132	23.49	
1945	3-18	1800	.464	.676	14.02	
1946	2-10	1115	.630	1.429	27.65	
1947	8-25	1320	.935	3.758	77.98	
1948	6-2	0615	.800	2.565	53.22	
1949	6-16	0720	.774	2.373	49.24	
1950	8-30	1600	.621	1.374	28.51	
1951	7-15	1250	.642	1.485	30.81	
1952	3-10	2300	.827	2.766	57.39	
1953	6-13	1900	.617	1.347	27.95	
1954	6-16	1120	.680	1.723	35.75	
1955						
1956						
1957						
1958						
1959						
1960						

SPECIAL WATER-YIELD COMPUTATIONS

Within the past few years two other methods of computing water yield have been tested and used to a limited extent at the Coweeta Hydrologic Laboratory. The first of these two methods was devised by the Mountain State Research Center, Northeastern Forest Experiment Station, and effects a considerable saving in computing time by reducing the number of points on the hydrograph used in the calculations. The second method is the application of the U. S. Geological Survey Discharge Integrator.

Northeastern Station Method

This method was adapted from U. S. Geological Survey techniques. Through a change in the conventional method of marking the charts, the office work involved in computing and tabulating water yield may be reduced by effecting a reduction in the number of points or "breaks" in the hydrograph used in the calculations. In the "Form 6 Method" described previously, calculation points were marked on the hydrograph at all breaks in the curve of the hydrograph and at all peaks and troughs as well as at midnight, storm beginning, and storm ending. In this method the breaks at storm beginning, maximum peak, and midnight are still utilized, but all other calculation points are made only where there is an appreciable rise or fall in discharge.

The allowable rise or fall before a calculation point is made depends upon a head-discharge relation that has been worked out and tabulated in a range table (table of permissible rise or fall in head for a given head range value). The permissible rise or fall is determined by the following rule: "Points on the hydrograph are made when the difference in discharge between consecutive heads exceeds one and one-half times the difference in discharge between heads where the previous break was made."

Using a 90° V-notch rating table, the range table may be derived by using the following procedure. Assume a head reading of 0.300 foot as a starting point. For the next reading use 0.310 foot. Referring to the rating table, the difference in discharge between the two head readings is 0.0109 c.f.s. One and one-half times this value is 0.0153 c.f.s. Refer again to the rating table and by inspection find the next highest paired values of head readings where the difference in discharge just exceeds 0.0153 c.f.s., i.e., 0.0154 c.f.s. In this case the paired head values are 0.369 and 0.379 foot. The difference between the head readings (0.369 - 0.300 or 0.069 foot) then is the permissible rise or fall in head for a head reading of 0.300 foot. This process may be repeated for each tenth of a foot change in head or at least often enough to define a curve of permissible rise in head over head for the range of values you expect to find on the hydrograph. The values for permissible rise in head are plotted against corresponding heads and a smooth curve is fitted to these data. From these curved values the final range table is made. The actual range of head values is arbitrary, i.e., 0.301 - .325, 0.326 - .350, etc., or 0.301 - .350, 0.351 - .400, etc. A range table constructed for the 90° and the 120° V notch weirs is given on the following page.

RI-SE
WATER RELATIONS
Streamflow
Computations
Area Coweeta

File No. 3.2231

U. S. Department of Agriculture
Forest Service
RANGE TABLE FOR COMPUTING WATER YIELD
BY NORTHEASTERN STATION METHOD

Head range (Feet)	Permissible rise or fall in head	
	90° V-Notch	120° V-Notch
	Feet	Feet
0.301- .350	0.092	0.080
.351- .400	.110	.100
.401- .450	.127	.110
.451- .500	.144	.120
.501- .550	.161	.140
.551- .600	.178	.150
.601- .650	.195	.170
.651- .700	.212	.180
.701- .750	.229	.200
.751- .800	.245	.210
.801- .850	.262	.230
.851- .900	.280	.240
.901- .950	.297	.250
.951-1.000	.315	.270
1.001-1.050	.331	.280
1.051-1.100	.350	.290
1.101-1.150	.365	.310
1.151-1.200	.382	.320
1.201-1.250	.400	.340
1.251-1.300	.416	.360
1.301-1.350	.434	.370
1.351-1.400	.450	.380
1.401-1.450	.468	.400
1.451-1.500	.485	.420
1.501-1.550	.501	.430
1.551-1.600	.519	.450
1.601-1.650	.537	.460
1.651-1.700	.555	.470

To illustrate the application of the table, assume that storm flow starts at a head reading of 0.831 foot. Referring to the range table, a permissible rise of 0.262 foot is indicated. The next computing point on the hydrograph would then be made where the head reading was 1.093 feet (0.831 plus 0.262), assuming that the maximum peak of midnight does not intervene.

The second step in the method is in the computing. Once the calculation points have been established, the exact head for the time interval between two consecutive points is determined by placing a plastic straightedge or template horizontally on that portion of the hydrograph in question and then balancing by inspection the areas above and below the edge or line and the curve (the areas bounded by the hydrograph curve, the horizontal line and the time ordinates of the two points--areas A and B in figure 5). Discharge is recorded only for the head reading at the intersection of the horizontal line and the hydrograph. This head value is multiplied by the time interval in seconds to obtain the interval discharge in cubic feet.

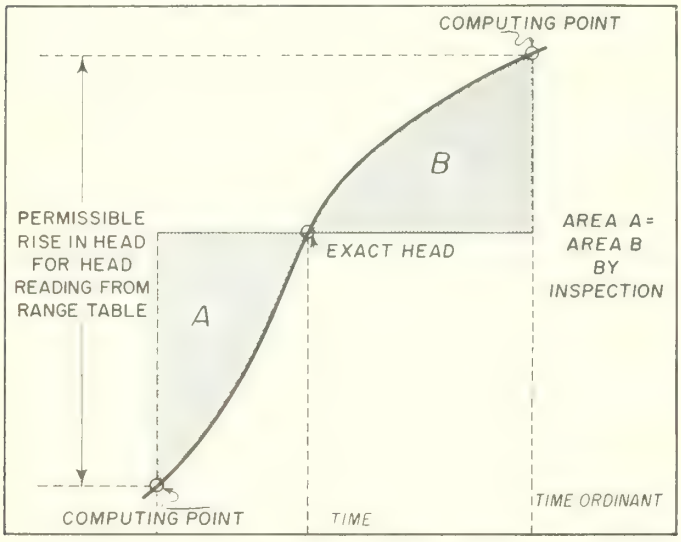

Figure 5.--Schematic representation of Northeastern method for weighting areas in determining an average head and estimating time interval for computing water yield.

Step one in this method results in a saving in computing time, since less than half as many points are marked on the hydrograph. The second step effects a reduction in office work, since only one entry for discharge is now necessary. Under the "Form 6" method it was necessary to enter discharge for each break and then average the values for the interval discharge.

The regular Form 6, Record of Runoff, may be adapted for use with this method. For comparison, runoff for the same storm period as used in illustrating the conventional method of computing water yield has been calculated and tabulated utilizing this method, and is given in the Record of Runoff on the following page. Note the difference between the two methods in number of entries and in water yield values. For the 6-day period the difference in water yields amounts to only 0.063 percent and the largest daily difference was 0.17 percent (for September 30) when compared with results obtained when the conventional method was used.

RI-SE
WATER RELATIONS
Streamflow
Water Yield

U. S. Department of Agriculture
Forest Service

RECORD OF RUNOFF BY NORTHEASTERN STATION METHOD

Form 6
File No. 3.2211

Expt. Area Coweeta
Station designation No. 7

Discharge rates from rating table dated: Dec. 1, 1934

Date 1936	Time	Time interval	Gage height	Discharge rate: For gage height	Discharge rate: Average for interval		Runoff from area: For interval		Runoff from area: Accumulated			Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
Sept.	Hr. min.	Min.	Ft.	C.f.s.	C.f.s.	In./hr.	Cu. ft.	Inches	Cu. ft.	Inches	C.s.m.	
28	0000	-										
	2400	1440	0.398	0.259			22,378		22,378			Sept. 28 total 22,378 c.f.
29	0200	120	0.401	0.264			1,901		1,901			SRB
	0345	105	0.420	0.296			1,865		3,766			P
	1735	830	0.394	0.252			12,550		16,316			SRB
	1830	55	0.425	0.305			1,007		17,323			P
	2100	150	0.510	0.478			4,302		21,625			
	2120	20	0.780	1.364			1,637		23,262			
	2200	40	0.992	2.470			5,928		29,190			P
	2300	60	1.040	2.776			9,994		39,184			T
	2355	55	1.047	2.823			9,316		48,500			
	2400	5	1.350	5.288			1,586		50,086			Sept. 29 Total 50,086 c.f.
30	0010	10	1.460	6.417			3,850		3,850			MP
	0220	130	1.192	3.889			30,334		34,184			T
	0350	90	1.086	3.090			16,686		50,870			P
	0930	340	0.986	2.434			49,654		100,524			
	2400	870	0.642	0.843			44,005		144,529			Sept. 30 Total 144,529 c.f.
Oct.												
1	2400	1440	0.500	0.455			39,312		39,312			Oct. 1 Total 39,312 c.f.
2	2400	1440	0.447	0.345			29,808		29,808			Oct. 2 Total 29,808 c.f.
3	2400	1440	0.427	0.308			26,611		26,611			Oct. 3 Total 26,611 c.f.
												Sept. 28 to Oct. 3 Total for period 312,724 c.f.

Tabulated by RD Date 3/55 Checked by JLK Date 3/55
Computed by CS Date 3/55 Checked by EAJ Date 3/55

Sheet 1 of 1 sheets

Tests on this method indicate that results obtained are within an error of plus or minus 2 percent for daily, weekly, or monthly discharges when compared to discharge values determined by both the Form 6 method and by using the U.S.G.S. Discharge Integrator.

It should be noted that this method cannot be used for storm studies without alteration and that additional experience is ordinarily required in properly selecting the exact head used in the computing.

Discharge Integrator

A discharge integrator has been developed by the U. S. Geological Survey for use in streamflow calculations. The integrator is shown in figure 6. It is designed to give discharge values directly in cubic feet per second. The basic principle of the integrator might be considered as a compensating planimeter. A different setting is required for each weir rating and type of chart. Once the proper adjustments have been made for these settings on the instrument, the integration or compilation of streamflow is very simple, accurate and rapid.

Detailed instructions and procedure for the operation of the discharge integrator have been outlined in U. S. Geological Survey publications.

When compiling streamflow data by means of the integrator at the Coweeta Hydrologic Laboratory, we use Form 8, shown on the following page. Discharge in mean daily c.f.s. is read directly from the instrument and by the application of appropriate conversion factors daily values may also be given in c.s.m., cubic feet, or area inches.

The discharge integrator effects a tremendous saving in time required for compiling water-yield data. After the instrument is properly set, approximately 1 year of stream discharge record may be computed in an 8-hour day.

Figure 6.- Discharge integrator.

RI-SE
WATER RELATIONS
Streamflow
Water Yield
Expt. Area Coweeta

U. S. Department of Agriculture
Forest Service
RECORD OF RUNOFF
BY DAYS FOR AN INDIVIDUAL DRAINAGE AREA

Form 8
File 3.2212

Watershed No. 7
Control 90° V-notch

Area 145.5 Acres
Conversion factor
c.f.s. to c.s.m.
4.400

Integrator setting Oct. 1954
Integrator operator W. Curtis
Compilation by B. Cunningham
Computed by C. Swafford, 3/55

Date	Mean daily c.f.s.	C.s.m.	Cubic feet	Area inches	Remarks
July 1936					
(1)	(2)	(3)	(4)	(5)	(6)
1	0.400	1.76	34,560	0.065	
2	.686	3.04	59,270	.113	
3	.448	1.97	38,710	.073	
4	.500	2.20	43,200	.082	
5	.400	1.76	34,560	.065	
6	.393	1.73	33,955	.064	
7	.380	1.67	32,830	.062	
8	.371	1.63	32,054	.061	
9	.380	1.67	32,830	.062	
10	.373	1.64	32,230	.061	
11	.382	1.68	33,005	.063	
12	.582	2.56	50,285	.095	
13	.458	2.03	39,570	.075	
14	.405	1.78	34,990	.066	
15	.382	1.68	33,005	.063	
16	.373	1.64	32,230	.061	
17	.441	1.94	38,100	.072	
18	.380	1.67	32,830	.062	
19	.359	1.58	31,020	.059	
20	.355	1.56	30,670	.058	
21	.375	1.65	32,400	.061	
22	.343	1.51	29,635	.056	
23	.339	1.49	29,290	.055	
24	.341	1.50	29,460	.056	
25	.334	1.47	28,860	.055	
26	.324	1.42	27,994	.053	
27	.314	1.38	27,130	.051	
28	.309	1.36	26,700	.051	
29	.312	1.37	26,960	.051	
30	.414	1.82	35,769	.068	
31	.413	1.81	35,680	.068	
Totals	12.266	53.97	1,059,782	2.007	

Ground Water Depletion Curves

The ground water depletion curve or the master recession curve is a useful hydrologic tool in various special studies. It is particularly applicable in the separation of base flow in storm hydrograph studies. Depletion curves may be constructed graphically by systematically matching arcs from a basin hydrograph or by arithmetic means. Only hydrographs for nonstorm periods are used for this purpose. A procedure used at the Coweeta Hydrologic Laboratory to calculate a depletion curve for a given drainage basin is described below.

The rate at which the ground water flow gradually decreases follows a die-away type exponential curve. For the time interval from maximum to lowest rates of ground water flow a depletion curve has been obtained by using the formula:

$$Q = Q_{oe} - kt \qquad (1)$$

where

Q = rate of discharge in c.s.m. at time t

Q_o = initial rate of discharge in c.s.m. at time t = o

e = base of natural logarithms

t = time in days

k = a watershed constant

A better fit of this decreasing ground water flow into a depletion curve has been obtained by using the formula:

$$Q = Q_o e^{-kt^n} \qquad (2)$$

In this equation n is another watershed constant. Equations (1) and (2) can be reduced to a linear form by taking common logarithms of both sides. For example, equation (2) in double logarithm form becomes:

$$\log (\log Q_o - \log Q) = n \log t + \log k - 0.36226$$

where corresponding to the familiar

$Y = ax + b$

$Y = \log (\log Q_o - \log Q)$

$x = \log t$

$a = \log k - 0.36226$

$b = n$

Once values of t and Q have been determined, equations (1) and (2) can be solved for the constants using the method of least squares.

During the period while ground water is diminishing, rains occur that produce storm flow which distorts the true time scale and does not permit the continuous development of a complete depletion curve. To overcome this, it is necessary to employ segments of the hydrograph that represent rainless periods. The mean daily discharges during the depletion season for all years on record are examined and tabulated for periods consisting of 6 or more successive days with ground water flow. Several methods may be used in this selection. For example, all nonstorm periods over 10 days are noted, and 4 days after the end of precipitation are allowed for removing any influence of subsurface flow. This results in a minimum series of at least 6 days of ground water depletion.

Another procedure has been to work directly with the stream hydrograph of mean daily discharge (fig. 4) and select the periods with distinct ground water flow. The individual periods are then arranged in order of decreasing magnitude, with the maximum discharge at the top. Table 1 shows how this arrangement of synchronizing the individual depletion periods is carried out.

Fitting the individual series from the various periods together for an average discharge requires some judgement. However, computers with varying degrees of experience have turned out essentially the same average series for plotting on logarithmic paper with no significant differences to the constants in equations (1) and (2). The method of least squares is used to fit the values of t and Q for computing the curve and formula. Figure 7 shows the derived curve for Coweeta Watershed No. 18.

For routine use, it is most convenient to convert the curve from figure 7 to read directly in gage height over the weir and adjust to the time scale of the original field chart. This adjusted curve is then transferred to transparent cloth or clear plastic and used as an overlay on the original record for separating base flow from storm hydrographs.

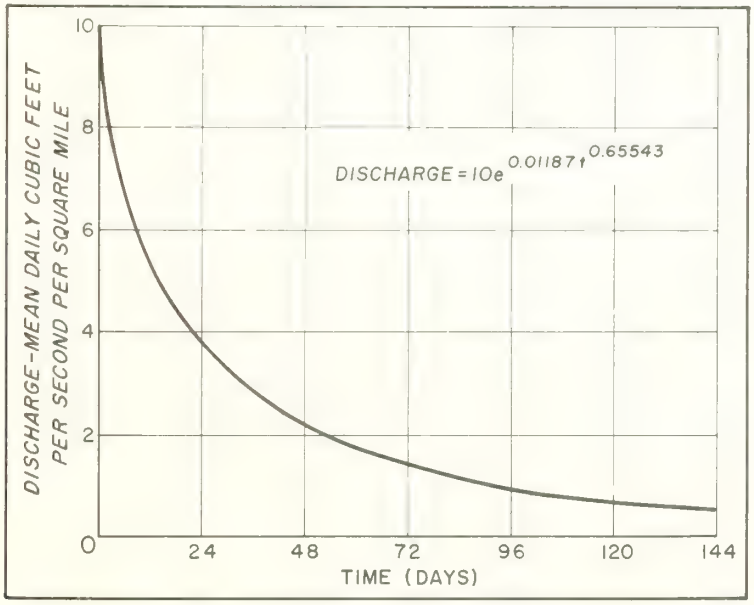

Figure 7.--Normal ground-water depletion curve, Watershed 18.

Table 1.--Procedure for synchronizing periods of base flow to derive normal curve of ground water depletion

t (Days)	Beginning date of periods: 4/2/44	4/11/49	3/12/39	4/4/39	4/13/48	Average depletion Q
	C.s.m.	C.s.m.	C.s.m.	C.s.m.	C.s.m.	C.s.m.
0	9.87	--	9.82	--	--	9.85
1	8.99	--	8.82	--	--	8.90
2	8.32	--	8.21	--	--	8.27
3	7.79	7.91	8.01	--	--	7.90
4	7.30	7.57	7.58	--	--	7.48
5	6.95	7.10	7.08	--	--	7.04
6	6.69	6.71	6.74	--	--	6.71
7	6.44	6.36	6.41	--	--	6.40
8	--	6.15	6.18	--	--	6.16
9	--	--	5.95	--	--	5.95
10	--	--	5.75	--	--	5.75
11	--	--	5.64	5.62	--	5.63
12	--	--	5.53	5.45	--	5.49
13	--	--	5.39	5.30	--	5.34
14	--	--	--	5.02	--	5.02
15	--	--	--	4.86	4.92	4.89
16	--	--	--	4.72	4.74	4.73
17	--	--	--	4.66	4.61	4.63
18	--	--	--	4.40	4.54	4.47
19	--	--	--	4.32	4.37	4.34
20	--	--	--	4.26	4.25	4.26

GROUND WATER

The third phase of basic water-resource accounting consists of recording and tabulating ground water data. Ground water levels or water table elevations from shallow wells can be measured and recorded by use of a water level recorder. Form 100, Record of Water Table Elevations, is used in compiling ground water data.

Record of Water Table Elevations--Form 100

Actual water table elevations may be read from the recorder chart for any desired time. Form 100 uses the hours of 8 a. m. or 5 p. m. or both. The readings are recorded by days and months on the form. Elevation of the water table above mean sea level is recorded unless otherwise specified and noted in the remarks section on the form. One sheet is used for the dormant season, November through April, and one for the growing season, May through October.

At the top of the form, appropriate information should be entered in the proper blanks to describe the well and the location. At the bottom of the form, space is provided for remarks, maximum, minimum, and range of water levels for the period. Forms 100 and 100a are shown on the following pages.

Ground Water Summaries

Ground water data are commonly summarized graphically by plotting daily values for the hydrologic year in the same fashion that stream discharge values are given. Figure 8 gives an example of such a summary.

For special studies such as daily fluctuations in the water table, hourly values may be taken from the recorder chart and either tabulated or shown graphically.

RI-SE
WATER RELATIONS
Ground Water

U. S. Department of Agriculture
Forest Service

Form 100
File No 3.51

WATER TABLE ELEVATIONS

Experimental Forest Coweeta — Well Number 6
Drainage Area 6 — Period: November 1, 1947 - April 30, 1948
Well Diameter ____ Dug Depth ____ Reference Iron Elevation 2352.45
Recorder 365-A Scale 1:1 Date Installed Sept. 29, 1938

Dormant Season

	November		December		January		February		March		April	
Date	8A	5P	8A	5P	8A	5P	8A	5P	8A	5P	8A	5P
1	2333.93		.51		35.42		35.22		35.66		36.63	
2	.94		.48		.39		.21		.63		.47	
3	.98		.45		.36		.22		.59		.40	
4	.99		.43		.34		.27		.54		.38	
5	.99		.42		.32		.34		.51		.35	
6	2334.07		.39		.32		.40		.50		.30	
7	.12		.38		.34		.44		.68		.26	
8	.17		.37		.36		.48		36.44		.19	
9	.23		.32		.37		.51		.79		.13	
10	.28		.29		.36		.55		.74		.16	
11	.29		.27		.36		.67		.58		.31	
12	.30		.26		.36		.86		.41		.38	
13	.37		.24		.38		36.73		.28		.31	
14	.48		.22		.36		37.85		.18		.27	
15	.66		.20		.31		38.63		.11		.19	
16	.86		35.18		.30		37.90		.02		.12	
17	2335.11		.23		.31		37.45		35.91		.06	
18	.45		.62		.32		.07		.80		35.97	
19	.72		.62		.32		36.82		.75		.90	
20	.82		.63		.33		.63		.68		.85	
21	.84		.64		.36		.46		.62		.83	
22	.83		.66		.36		.36		.59		.78	
23	.81		.67		.35		.21		.57		.73	
24	.78		.66		.35		.10		.52		.70	
25	.74		.63		.30		.01		.50		.68	
26	.71		.62		.28		35.97		.51		.65	
27	.65		.59		.27		.89		.64		.61	
28	.61		.54		.27		.84		37.35		.59	
29	.57		.50		.25		.73		.28		.57	
30	.55		.47		.24				.00		.55	
31			.43		.23				36.82			

Remarks M.P. 11/21 - 2335.84 M.P. 2/15/48 - 2338.92 M.P. 3/28/48 - 2337.45

Maximum for Period 2338.92 2/15 Minimum for Period 2333.93 11/1 Maximum Range 4.99

Observer: R. S. Pierce Recorder: R. S. Pierce Checked by: E. A. Johnson

Elevation of the water table above mean sea level is recorded unless otherwise shown by remarks. The figures for hundreds of feet are omitted. Example, 2264.12 is recorded as 64.12.

RI-SE
WATER RELATIONS
Ground Water

U. S. Department of Agriculture
Forest Service

Form 100a
File No. 3.51

WATER TABLE ELEVATIONS

Experimental Forest Coweeta — Well Number 6
Drainage Area 6 — Period: May 1, 1948 - October 31, 1948
Well Diameter ____ Dug Depth ____ Reference Iron Elevation 2352.45
Recorder 365-A Scale 1:1 — Date Installed Sept. 29, 1938

Growing Season

Date	May 8A	May 5P	June 8A	June 5P	July 8A	July 5P	August 8A	August 5P	September 8A	September 5P	October 8A	October 5P
1	35.53		35.19		34.83		.08		35.13		.64	
2	.52		.16		.82		.08		.11		.64	
3	.51		.15		.81		.57		.09		.60	
4	.50		.15		.80		.72		.07		.60	
5	.48		.13		.78		36.05		.06		.60	
6	.47		.12		.79		.22		.04		.59	
7	.47		.11		.78		.27		.02		.58	
8	.45		.10		.76		.23		.01		.58	
9	.44		.09		.76		.15		34.99		.56	
10	.43		.07		.75		.05		.97		.56	
11	.43		.06		.75		35.94		.96		.56	
12	.42		.05		.75		.85		.91		.56	
13	.42		.05		.76		.77		.89		.56	
14	.41		.03		.80		.69		.87		.55	
15	.39		.02		.84		.63		.76		.54	
16	.38		.01		.84		.58		.73		.53	
17	.37		.00		.84		.54		.69		.53	
18	.35		34.99		.88		.50		.68		.52	
19	.33		.98		.94		.46		.67		.52	
20	.32		.97		35.00		.42		.66		.50	
21	.31		.95		.05		.40		.65		.50	
22	.30		.94		.08		.38		.73		.42	
23	.28		.94		.10		.35		.70		.43	
24	.25		.93		.12		.31		.68		.42	
25	.24		.91		.12		.29		.65		.40	
26	.24		.90		.13		.27		.65		.41	
27	.23		.88		.12		.24		.63		.40	
28	.22		.87		.12		.21		.62		.39	
29	.21		.87		.12		.19		.67		.39	
30	.21		.85		.11		.18		.66		.39	
31	.19				.09		.16				.38	

Remarks: M.P. 7/25 - 2335.12, 8/7 - 2336.27

Maximum for Period 2336.27 8/7 Minimum for Period 2334.37 10/30 Maximum Range 1.90

Observer: R. S. Pierce Recorder: R. S. Pierce Checked by: E. A. Johnson

Elevation of the water table above mean sea level is recorded unless otherwise shown by remarks. The figures for hundreds of feet are omitted. Example, 2264.12 is recorded as 64.12.

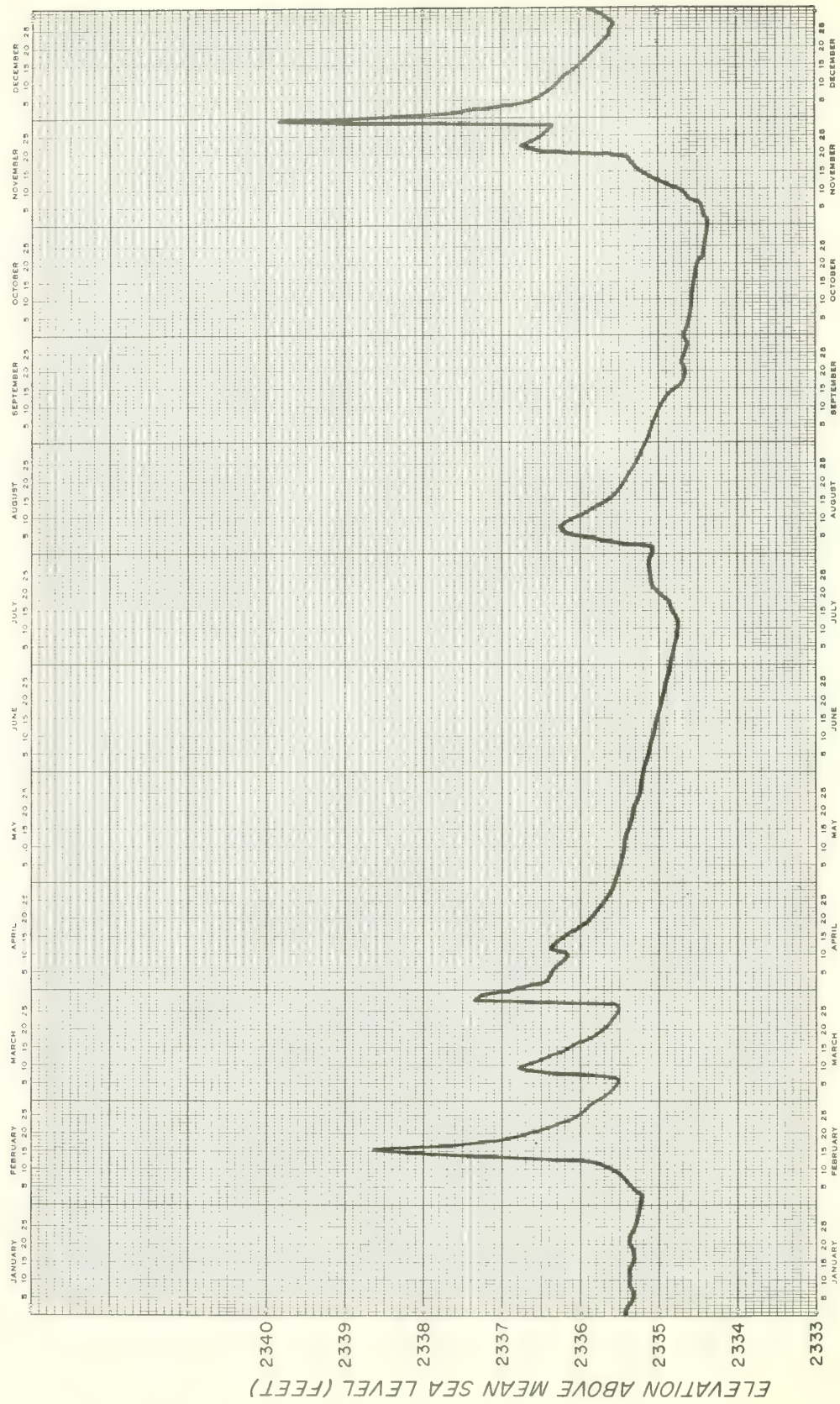

Figure 8.--Water table elevations at 8 A. M. from Well No. 6 for 1948.

CONVERSION FACTORS

Area:

acres to square miles = $\frac{\text{Acres}}{640}$

Rate:

c.f.s. to c.s.m. = $\frac{\text{c.f.s.}}{\text{square mi.}}$ or $\frac{640}{\text{area}}$ x c.f.s.

c.f.s. to in./hr. = $\left(\frac{3600}{43560 \times \text{acres}}\right)$ x 12

c.s.m. to in./hr. = c.s.m. $\left(\frac{3600}{43560 \times 640}\right)$ x 12

c.f.s. to a./f. per day = c.f.s. $\left(\frac{86400}{43560}\right)$

c.s.m. to depth per day (inches) = c.s.m. $\left(\frac{86400}{43560 \times 640}\right)$ x 12

Volume:

cu. ft. to cu. ft. per sq. mi. = $\frac{\text{cu.ft.}}{\text{sq.mi.}}$ or $\frac{640}{\text{area}}$ x cu. ft.

cu. ft. to area inches = cu. ft. $\left(\frac{1}{43560 \times \text{acres}}\right)$ x 12

cu. ft. to mean daily c.s.m. = cu.ft. $\left(\frac{1}{86400 \times \text{sq. mi.}}\right)$

cu. ft. to a./f. = $\frac{\text{cu. ft.}}{43560}$

Agriculture--Asheville

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August 1956

Experimental Air-layering of Shortleaf and Loblolly Pine

by Bratislav Zak

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

Closeup of air-layered stem of $2\frac{1}{2}$-year-old shortleaf pine seedling, showing abundant root development 36 days after beginning of treatment.

EXPERIMENTAL AIR-LAYERING OF SHORTLEAF AND LOBLOLLY PINE

by

Bratislav Zak
Southeastern Forest Experiment Station
in cooperation with
The School of Forestry, University of Georgia, Athens, Georgia

INTRODUCTION

Methods currently available for the vegetative propagation of the genus Pinus in forest genetics programs in the South and Southeast include grafting, rooting, and air-layering. Of these, only grafting has developed into a practical tool. It already is being used to establish seed orchards in Georgia and Florida with scion material from selected trees. But rooting and air-layering are in many ways more desirable forms of vegetative propagation, since, unlike grafting, they reproduce the genotype of the parent tree in both the top and root system of the new plant. Unfortunately, rooting for most species of pine is as yet difficult, and is therefore of limited use in experimental work. Air-layering of pine, as first used by Mergen (4) on slash pine, offers promise as a practical tool, at least on younger trees.

Methods of vegetative propagation whereby the root system of the parent tree can be multiplied are especially useful in studying the genotype of selected individuals. This is especially true in pathological studies where an attempt is made to incorporate resistance to a root induced disease. Where only the above-ground parts are attacked, such as in the white pine blister rust disease, it may be practical to graft scions from selected trees and test these "progeny" for resistance to infection (1).

Tree diseases such as littleleaf of pine (2), originating in the root system, are not amenable to such treatment. The causal factors of littleleaf include the soil fungus, Phytophthora cinnamomi, and associated adverse soil conditions. The root system itself must be tested against this complex in seeking an inherited resistance to littleleaf. Currently, selected trees are being subjected to examination by testing 1-year-old open- and control-pollinated seedlings (6). Information on the genotype of these parent trees could be obtained more accurately and rapidly by use of rooted material.

The basic simplicity of rooting cuttings makes this method appealing for genetics use. The method has found wide application in horticulture but only limited use in forest genetics research because of rather meager and erratic success with trees, especially pines. More complete understanding of the physiological and environmental conditions is needed if this method is to be pursued successfully. Furthermore, the factors involved in the effect of age

upon rootability are not well understood. Age of the parent tree determines how easily material from it will strike roots; shoots from trees beyond 10 years of age are rooted only with difficulty.

Attention has turned recently in the Southeast to the possible use of air-layering to supplement and even replace the rooting of cuttings from pine. The method has been used successfully by Mergen (4) with 5- to 17-year-old slash pines; he obtained 85 percent success using Hormodin No. 3[1/] and 50 percent without this auxin. He did not compare rooting of the branches for the different ages used. Cech (3) had good results air-layering branches on 3- to 5-year-old loblolly pines. Beyond this age, root formation was difficult, although a few rooted air-layers were obtained from trees up to 60 years old.

The present study reports preliminary trials in air-layering shortleaf and loblolly pine, not for the practical purpose of vegetative propagation but rather to study factors involved in the rooting of cuttings. Elaborate experimental layouts involving several thousand cuttings and different treatments commonly fail to yield even one successfully rooted cutting. The greater and more uniform success of air-layering provides an opportunity for studying and evaluating responses to physiological and environmental treatments. The similarity between these two forms of vegetative propagation allows the ready transfer of conclusions with, of course, some reservation.

METHODS AND RESULTS

General

The techniques of air-layering as described by Mergen (4) and variations thereof were applied mainly to $2\frac{1}{2}$-year-old potted shortleaf and loblolly seedlings. A few were made on branches of two shortleaf pine grafts made 8 years previously, using scion material from 35-year-old trees. In brief, the basic procedure was as follows: The needles were removed from the branch or main stem to be treated, and a $\frac{1}{2}$-inch wide band of bark removed by first scoring the bark with a knife. Care was exercised to avoid cutting into the sapwood. (Air-layers often failed in first attempts because knife cuts were too deep and penetrated the sapwood.) The bark was then peeled off with the fingers. The exposed sapwood was not scraped and in no case was there a bridging of the gap by callus tissue. Auxin when applied was Hormodin No. 3. This was dusted with a small brush onto the upper cut bark surface. Next, the treated area was enveloped in a handful of moist sphagnum moss, which was then tightly encased in a sheath of polyethylene plastic. Finally, the whole was loosely wrapped in aluminum foil to reduce heat buildup within.

1/ 0.8 percent indolebutyric acid in talc.

Air-Layering in Trough

A modified method of applying sphagnum moss to the air-layered stem was tried. A wooden trough 6 in. x 6 in. x 10 ft. was made with loose bottom joints to allow drainage of excess water. At 6-inch intervals, opposite-aligned slots $\frac{1}{2}$ in. x 3 in. were cut downward in the sides. Moist sphagnum moss was packed in the bottom up to the lower level of the slots and the girdled seedling stems inserted horizontally. This permitted the foliage to be fully exposed to sunlight; the intact root system was mulched in sawdust. More sphagnum moss was added, completely filling the box. Finally, a cover board sheathed with aluminum foil was installed over the top (fig. 1). This was removed periodically for examination and for watering when necessary. The method gave excellent results.

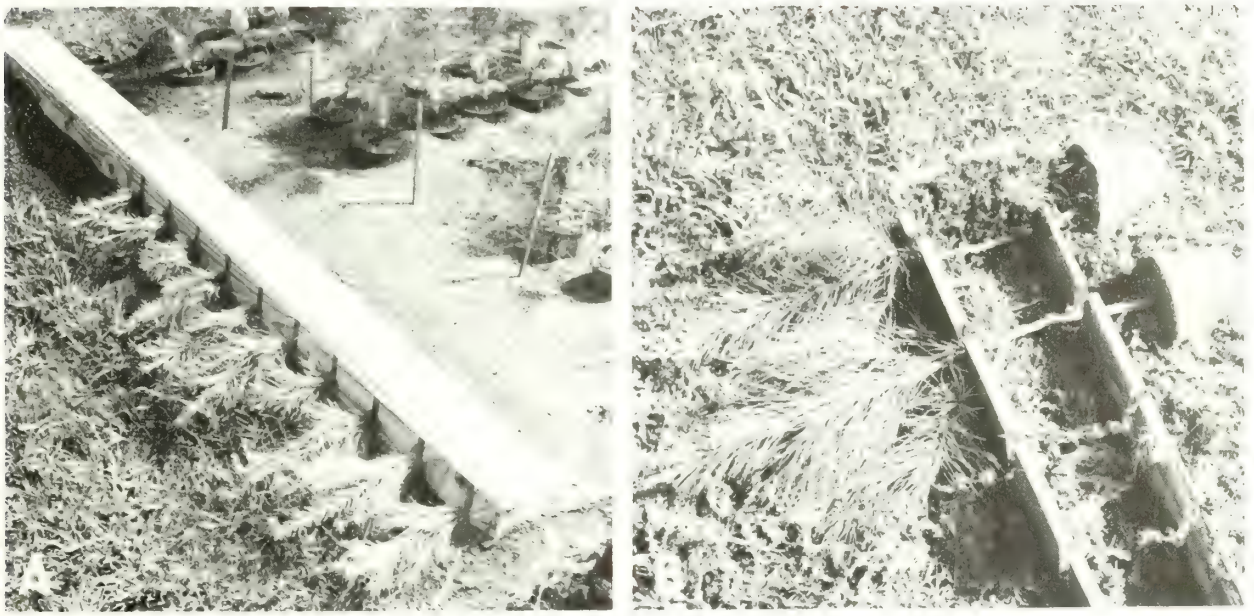

Figure 1.--Trough method of air-layering seedlings. A, Completed trough with seedlings in place and roots mulched in sawdust. B, Closeup of open trough with seedling stems inserted in slots.

Synthetic Sponge as Rooting Medium

A substitute for sphagnum moss as rooting medium was tried in air-layering the stems of upright seedlings. DuPont synthetic sponge was used with good results (fig. 2) by cutting two blocks 2 in. x $1\frac{1}{2}$ in. x $1\frac{1}{4}$ in. from a larger washing sponge and gouging out small cavities in each. After the sponge blocks had been wet and squeezed for excess water, they were applied to the girdle and then encased firmly in a sheath of polyethylene plastic. A loose covering of aluminum foil completed the air-layer.

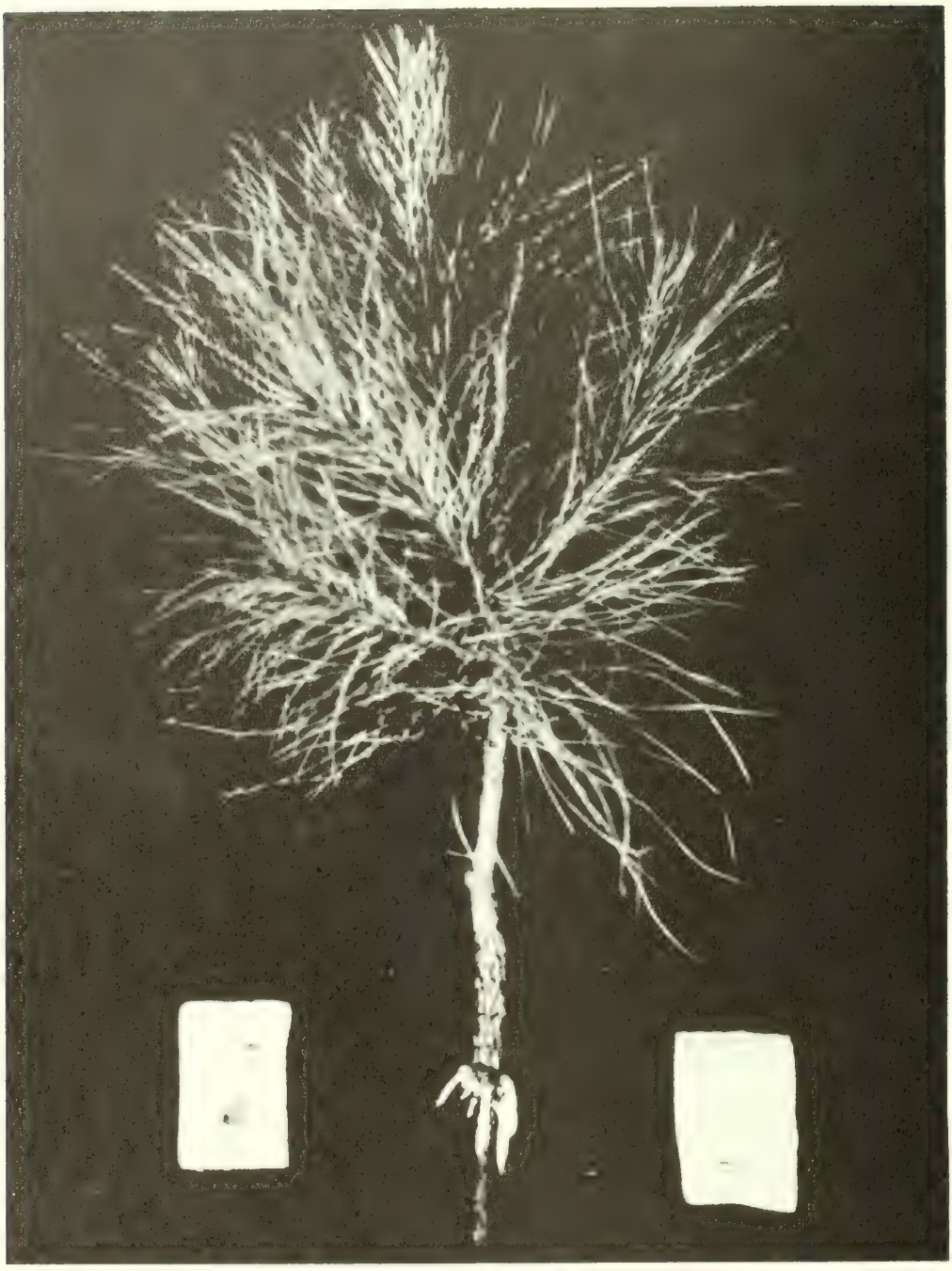

Figure 2.--Shortleaf pine seedling stem after 38 days air layering, with DuPont synthetic sponge as rooting medium.

Actually the roots did not enter the rather dense plastic material but grew in the cavities between the two blocks. A more "open" material molded into two fusiform halves would be ideal for this purpose and would simplify making the air-layer, particularly in the crowns of larger trees. Possibly sphagnum moss can be so processed by incorporating a binder and then molding. Or blocks of natural peat moss, sold as peat moss seedling pots, may be adapted for this use.

Shortleaf Versus Loblolly Pine

To test the difference between shortleaf and loblolly pine in rootability by air-layering, 10 seedlings of each were air-layered along their main stem by the "trough" method. Auxin treatment consisted of an application of Hormodin No. 3. The air-layers, made in June, were examined after 53 days and data on root development noted. As shown in table 1, 8 of 10 shortleaf and only 6 of 10 loblolly pine air-layers developed roots. This difference between the two species is even more effectively shown by the average number of roots per rooted seedling and by the average total length of main roots per rooted seedling. A representative seedling of each species is illustrated in figure 3.

Table 1.--Air-layered stems of $2\frac{1}{2}$-year-old seedlings after 53 days; shortleaf versus loblolly pine

Species	Stems air-layered	Stems rooted	Average roots per stem 1/	Average total length of main roots per stem 1/ 2/
	Number	Number	Number	Inches
Shortleaf	10	8	15.5	108.6
Loblolly	10	6	6.6	45.7

1/ Based on stems rooted.
2/ Does not include side roots--only those originating from callus zone.

With and Without Auxin

A group of shortleaf pine seedlings was air-layered upright along their stems to test the effect of auxin on rooting. Twelve seedlings were air-layered without the use of auxin, and 12 with an application of Hormodin No. 3. Begun early in August, the test was concluded after 45 days. The results (table 2) demonstrate that auxin greatly aided formation of roots. Other studies will determine the most favorable concentrations for pine of different ages.

Table 2.--Air-layered stems of $2\frac{1}{2}$-year-old shortleaf pine seedlings after 45 days; effect of auxin on root development

Treatment	Stems air-layered	Stems rooted	Average roots per stem 1/	Average total length of main roots per stem 1/ 2/
	Number	Number	Number	Inches
Control	12	9	4.7	0.7
Hormodin No. 3	12	12	10.0	6.0

1/ Based on stems rooted.
2/ Does not include side roots--only those originating from callus zone.

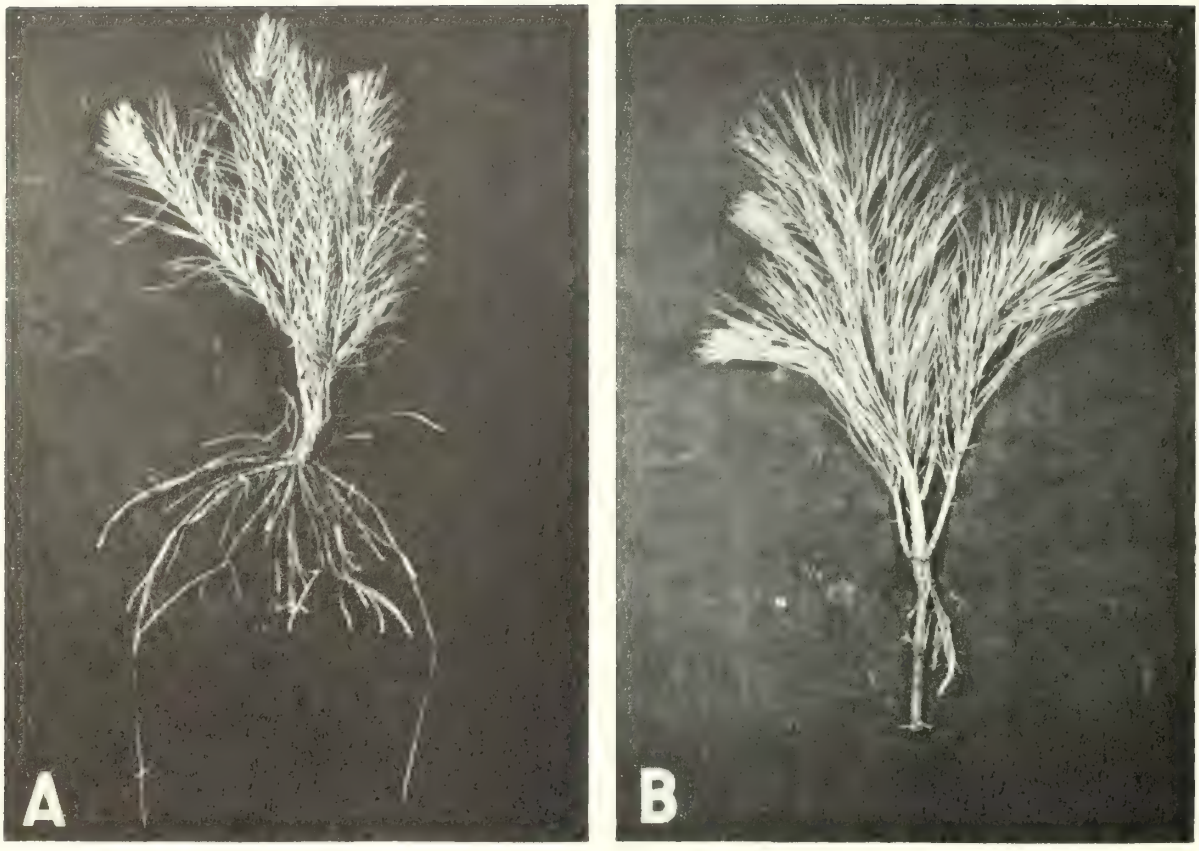

Figure 3.--Air-layered $2\frac{1}{2}$-year-old shortleaf and loblolly pine. Former species exhibited much greater root forming ability. A, Shortleaf pine. B, Loblolly pine.

Air-Layering Grafted Pine

Branches on two shortleaf pine grafted trees, one made 8 and the other 9 years ago and now 10 to 12 feet in height, were air-layered using Hormodin No. 3. The original scion parents were 35 to 40 years old at the time of grafting. Of 11 air-layers made in June on the younger tree and 14 on the older tree, only one, on the latter, showed signs of root development after 65 days. The single successful air-layer had only one root and it was only 1/8 inch in length.

Thomas and Riker (5), rooting eastern white pine cuttings, also experienced poor rooting of cuttings taken from grafted trees made with scions from mature trees in the field. The grafted trees reacted like adult trees. Cech (3) has had good results with both cuttings and air-layers on young loblolly pine but little success with older trees. Others have encountered similar difficulties when attempting to propagate from older trees by these methods. The author feels that although current growth shoots on older trees are "young" in a developmental sense, their tissues, nevertheless, may also be considered physiologically "old" in that they contain elements of aging passed on and accumulated from growing season to growing season.

Air-Layering of Needle Fascicles

A modified form of air-layering needle fascicles or dwarf shoots was devised for possible use in vegetatively propagating shortleaf and other pines. For this work, $2\frac{1}{2}$-year-old potted shortleaf pine seedlings again served as test plants. First, needle fascicles were thinned from a 3-inch length of stem 12 inches above ground to allow more working space for the remaining needles. Then, beginning about $\frac{1}{4}$ inch below the needle fascicle base, an upward cut was made with a sharp thin-bladed knife. This produced a slab of bark and wood from 1/2 to 5/8 inch long, 3/16 inch wide, and 1/16 to 1/32 inch thick, bearing a needle fascicle and attached solely at its upper point to the main stem. As many as 12 such slabs were made on individual stems along a 3-inch length. Finally, Hormodin No. 3 was dusted onto the cut surfaces and the treated area enveloped in moist sphagnum moss for 45 to 60 days.

Callus formation from each slab was excellent (fig. 4). And, from many of these callus areas one or two roots protruded (fig. 5), some being over 4 inches long, with side roots. Those slabs, both with and without roots, still bearing their needle fascicles were next severed from the stem and planted in a coarse sand-peat moss mixture in a warm greenhouse to force growth of the apical meristem. High humidity was maintained and, as this phase took place during fall and winter, day length was increased 3 hours by use of artificial light.

The method was first tried in August on 10 seedlings by means of the "trough" procedure previously discussed. After 42 days the stems were exposed and examined; the results for individual trees are presented in table 3. All needle fascicle slabs developed callus tissue but only 13 percent formed roots. Those of both groups still bearing needles were planted in the greenhouse. This included 10 slabs with roots and 66 slabs without roots. After 4 months, 9 in the first group were dead--one remained alive but showed no sign of top growth. In the second group, 44 of the 66 slabs died--of the remaining 22 only one formed roots after planting. All lacked any evidence of top growth.

A second trial was made in mid September on the upright stems of 9 shortleaf pine seedlings. This time $\frac{1}{4}$-inch lengths of toothpick were inserted under the slabs, which had been cut to separate them from the main stem and so prevent reunion. Hormodin No. 3 was dusted over the cut surfaces, sphagnum moss applied, and the whole enveloped in polyethylene plastic sheeting. No other covering was used.

Results after 65 days are seen in table 4. For all trees, 76 percent of the air-layered slabs formed callus tissue and 55 percent bore roots, many as long as 4 inches and with side roots. The piece of toothpick inserted under each slab helped in preventing union with the stem; several slabs with roots were quite free and were easily severed.

Figure 4.--Needle fascicle air-layering on stem of shortleaf pine seedling. Shows callused tissue below fascicle bases before root initiation.

Table 3.--First needle fascicle air-layering on $2\frac{1}{2}$-year-old shortleaf pine seedlings after 42 days

Tree number	Fascicle slabs	
	Air-layered	Forming roots 1/
	Number	Number
1	9	1
2	12	0
3	10	0
4	10	0
5	10	3
6	10	0
7	10	5
8	10	0
9	10	4
10	10	0
Total	101	13
Percent		13

1/ All of the air-layers callused.

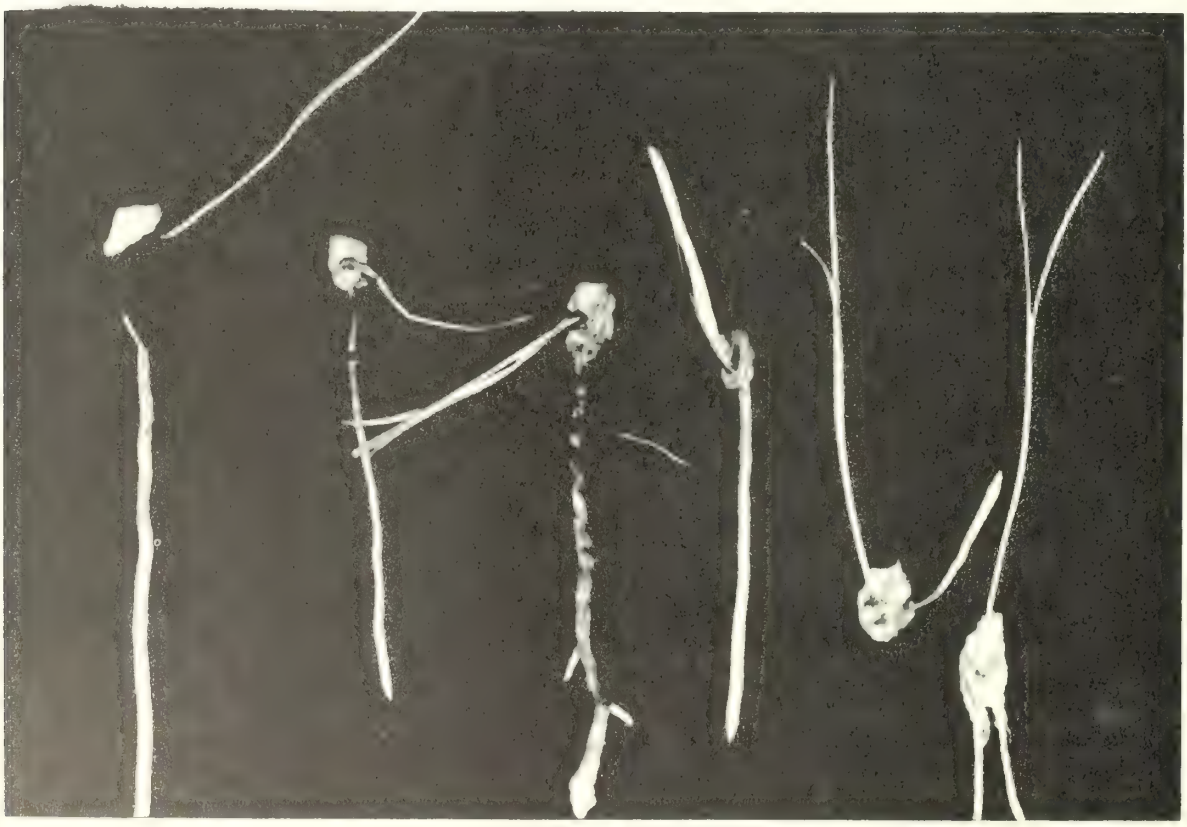

Figure 5.--Needle fascicles with supporting tissue and roots, severed from seedling stem ready for planting.

Table 4.--Second needle fascicle air-layering on $2\frac{1}{2}$-year-old shortleaf pine seedlings after 65 days

Tree number	Fascicle slabs			
	Air-layered	Callused		
		With roots	Without roots	Total
	Number	Number	Number	Number
1	8	5	0	5
2	8	4	2	6
3	6	3	2	5
4	7	5	0	5
5	5	3	0	3
6	8	6	0	6
7	6	3	2	5
8	6	3	1	4
9	8	2	6	8
Total	62	34	13	47
Percent		55	21	76

For this second test, 22 of the slabs with roots and 18 without roots and still retaining their needle fascicle were planted under conditions similar to those in the first study. Daylight was supplemented with 3 hours of artificial light. One month later, needle fascicles borne by 3 of the 22 slabs with roots showed beginnings of shoot growth from their bases. After 3 additional weeks, the new growth amounted to about $1\frac{1}{2}$ inches for each (fig. 6). These complete little trees were transplanted into a soil-sand mixture and have continued growth since.

Admittedly, the method described has at present little practical value as a tool for the forest geneticist. It, in common with rooting and general air-layering of pine, has a serious limitation imposed by age, in that older trees are difficult if not impossible to propagate. In addition, there is the problem of forcing growth, or breaking dormancy, of the dwarf shoot or needle fascicle after roots have been induced by air-layering. These and other problems relating to this method must be solved before it can have wide use in forest genetics.

Figure 6.--Complete little tree produced by air-layering shortleaf pine needle fascicle. Air-layering continued 65 days, followed by 48 days in soil-sand mixture to break dormancy of the apical meristem in the base of the fascicle.

CONCLUSIONS

These experiments in air-layering shortleaf and loblolly pine show that the general branch method can be successfully applied to young trees. With older trees, this method shows much the same lack of success as the rooted cuttings method does; so reliance must still be placed on grafting for vegetatively propagating older material. The much better results obtained with air-layering than with the rooting of severed cuttings can, of course, be attributed to the continuity of xylem tissue from parent tree to the treated branch. The benefit may be interpreted as an adequate source of water and nutrients, permitting uninterrupted transpiration and normal metabolism. Full sunlight can be utilized for maximum photosynthesis to provide high accumulations of food in tissue from which roots originate.

Further studies, with the air-layering technique used as a tool, will attempt to find out why we get roots from the xylem-connected air-layered branch but few or none from the severed cutting. Eventually, it is hoped, techniques of rooting can be modified for successful use in forest genetics.

SUMMARY

Several modifications of the air-layering technique as applied to the stems of $2\frac{1}{2}$-year-old shortleaf and loblolly pine seedlings and to branches of grafted shortleaf pine are described and discussed. The use of air-layering as a tool to study factors involved in the rooting of severed cuttings is considered.

A method of air-layering potted seedlings horizontally in a wooden trough filled with sphagnum moss is described.

Blocks of DuPont synthetic sponge were tried successfully as a substitute for sphagnum moss as the rooting medium in air-layering. A less dense material molded into fusiform halves is suggested.

Comparable $2\frac{1}{2}$-year old potted shortleaf and loblolly seedlings were air layered to test species differences. Shortleaf exhibited a much greater root-forming ability than loblolly pine.

The effect of Hormodin No. 3 (0.8 percent indolebutyric acid) was tested in air-layering $2\frac{1}{2}$-year-old shortleaf pine seedlings. Application of this auxin greatly aided root formation.

Two shortleaf pine grafted trees, with grafts made 8 and 9 years ago from scion material of adult trees, were air-layered with poor results. The almost complete lack of success is attributed to physiologic age of the tissue.

A method of air-layering pine needle fascicles is described and the results for $2\frac{1}{2}$-year old shortleaf pine seedlings are presented. In one trial, 55 percent of tissue slabs bearing needle bundles produced roots. Three such "rooted" fascicles, or dwarf shoots, broke dormancy and commenced shoot growth to become complete, fully established little trees.

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Hardwood Timber Resources in Central and Northern Georgia

by

Robert W. Larson

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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The purpose of this report is to bring together from the Forest Survey detailed information on the makeup and use of the hardwood resource of central and northern Georgia. This information was particularly needed in the planning of a new research project on the management of Piedmont hardwoods at the Athens-Macon Research Center. It should also be of direct interest to the many foresters and forest industries whose future is tied in with the hardwood resources of the area.

Grateful acknowledgment is made to Dr. Thomas C. Nelson and other personnel of the Athens-Macon Research Center for summarization of data on which many of the charts in this publication are based; also to the Graphics Unit, National Weather Records Center, Weather Bureau, U. S. Dept. of Commerce, Asheville, N. C., for drafting the charts and maps.

HARDWOOD TIMBER RESOURCES IN CENTRAL AND NORTHERN GEORGIA

By

Robert W. Larson

INTRODUCTION

A belt of gently rolling hills, known as the Piedmont plateau, separates the rugged Appalachian mountain range from the low, level plain along the Atlantic and Gulf coast (fig. 1). The rolling nature of the land, along with heavy rainfall and a long winter period during which the land is left without the protection of growing vegetation, makes the soils especially susceptible to erosion and loss of fertility. Since settlement began, it has been a common practice to crop a field for several years until yields began to drop, abandon it, and clear new land. A large share of the land in this region has gone through at least one cycle of clearing, abandonment, and reversion to forests. There probably is very little land outside of the swales and swampy river bottoms which at some time or another in the past has not been cropped.

After this region became settled, the amount of land in agriculture did not fluctuate a great deal; land clearing tended to balance land abandonment. But following the Civil War, the depression of the 1880's, and the boll weevil invasion of the cotton fields in the early 1920's, land abandonment far exceeded land clearing. Agricultural land shrank and forest land increased.

Much of the agricultural land allowed to revert to forest during these periods of widespread abandonment never was returned to agriculture, and the area of forest land has continued to increase up to the present time. Every year during the past 15 to 20 years, forests have invaded over a fourth of a million acres in the Piedmont regions of Virginia, North Carolina, South Carolina, and Georgia. In 1953 forests covered 68 percent of the total land area, compared to 56 percent in 1936.

While hardwood forests made up of oaks, hickory, gum, and yellow-poplar originally covered most of this region, pines rather than hardwoods invade the abandoned fields. Thus, the immediate result of wide-scale land abandonment is a big increase in the area of pine type. Hardwood species, however, soon make their appearance in the understory of the pine stands. On the hot, dry southern slopes and ridges, which are not especially well suited to the growth of hardwoods, hardwoods replace pine slowly. But on the northern slopes, especially on the deep, moist soils, an understory of almost pure hardwoods has frequently become established by the time the pine is large enough to cut.

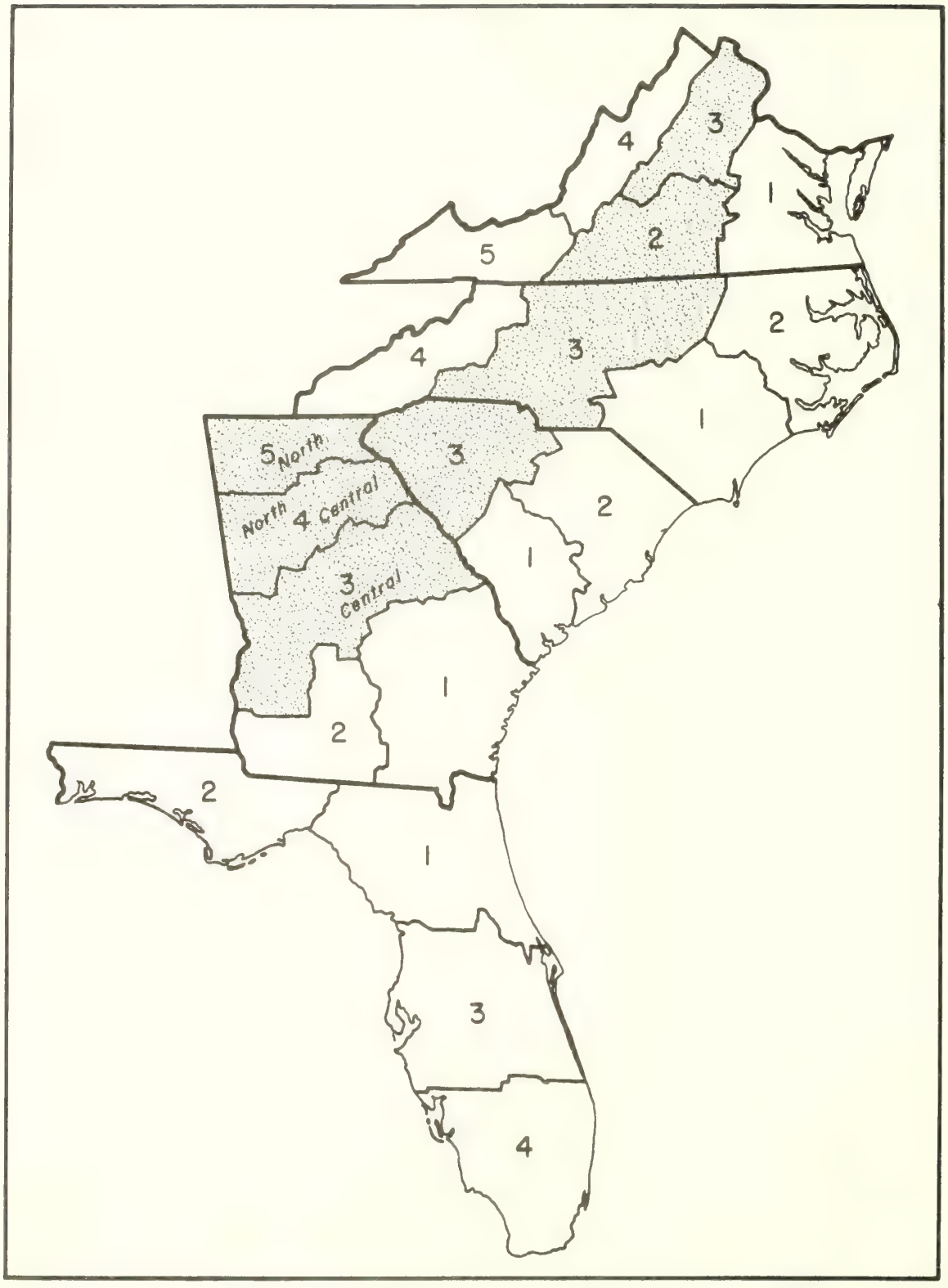


Figure 1.--Location of the Piedmont Forest Survey Units in Virginia, North Carolina, South Carolina, and Georgia.

This conversion of pine to hardwood stands is hastened by repeatedly cutting out the pine and leaving the hardwoods. Since 1936, the area of hardwood type has increased by about 5 million acres, while the area of pine type has remained about the same, in spite of wide-scale seeding in of pine on abandoned farmland. The proportion of hardwood type has increased from about 30 percent in 1936 to 42 percent in 1953. Prevailing cutting practice not only hastens the conversion of pine stands to hardwoods but reduces the quality of timber. The best quality hardwoods are usually cut along with the pine, leaving stands choked with the less desirable species and short, limby, crooked and rotten culls. Thus, forest industries dependent upon this region for their timber supply are faced with an ever-increasing volume of low-grade hardwoods for which they have little or no use. Timber landowners are confronted with an ever-increasing volume of this unsalable timber which is preventing the establishment and growth of the pine and good-quality hardwoods they could sell.

A recent forest survey completed in 1953 provides up-to-date information on timber volume and forest conditions in central and north Georgia. Survey crews examined 6,712 ground plots scattered over 13.1 million acres of forest land in the three northern forest survey units in Georgia. Although the Piedmont plateau makes up the largest part of these survey units, this area also includes parts of the Blue Ridge and Appalachian valleys in the north, and the Sandhills and part of the Coastal plain in the south (fig. 2). These areas differ mainly in their geologic origin; that is, they are not part of the uplifted and dissected plain which forms the Piedmont plateau. However, areas adjoining the Piedmont plateu resemble the Piedmont in forest characteristics. They present the same problems associated with shifts from pine and high-grade hardwoods to low-quality hardwoods. No attempt has been made to separate these areas in analyzing the data.

FOREST AREA AND TYPES

Central and north Georgia contain 13.3 million acres, of which 63 percent is forest. Although it is believed that hardwoods originally covered most of the land, only 4.7 million acres, or 35 percent of the forest land, now supports hardwood types, i.e., stands in which 75 percent or more of the volume is in hardwood trees. About 2.6 million acres are oak-hickory type growing on well drained uplands, while 1.9 million acres are oak-gum-cypress types growing in the wet lowlands and river bottoms. Scrub oak is the principal species on 229,000 acres, most of which is in the Sandhills region (fig. 2). An additional 1.6 million acres, or 12 percent of the forest area, supports oak-pine type, stands in which half to 75 percent of the volume is in hardwood trees.

The trend is toward more forest land, and a greater proportion of the forest area is hardwood types. Between 1936 and 1953, the area of forest land in this area increased 21 percent. Most of this new forest land is abandoned farmland which reverted to forest--mainly pine type. However, this increase in pine type was nearly offset by the reversion of pine type to hardwood on other forest area. While pine types increased less than 2 percent, the area of hardwood types increased 76 percent between surveys--an annual increase of 4.2 percent.

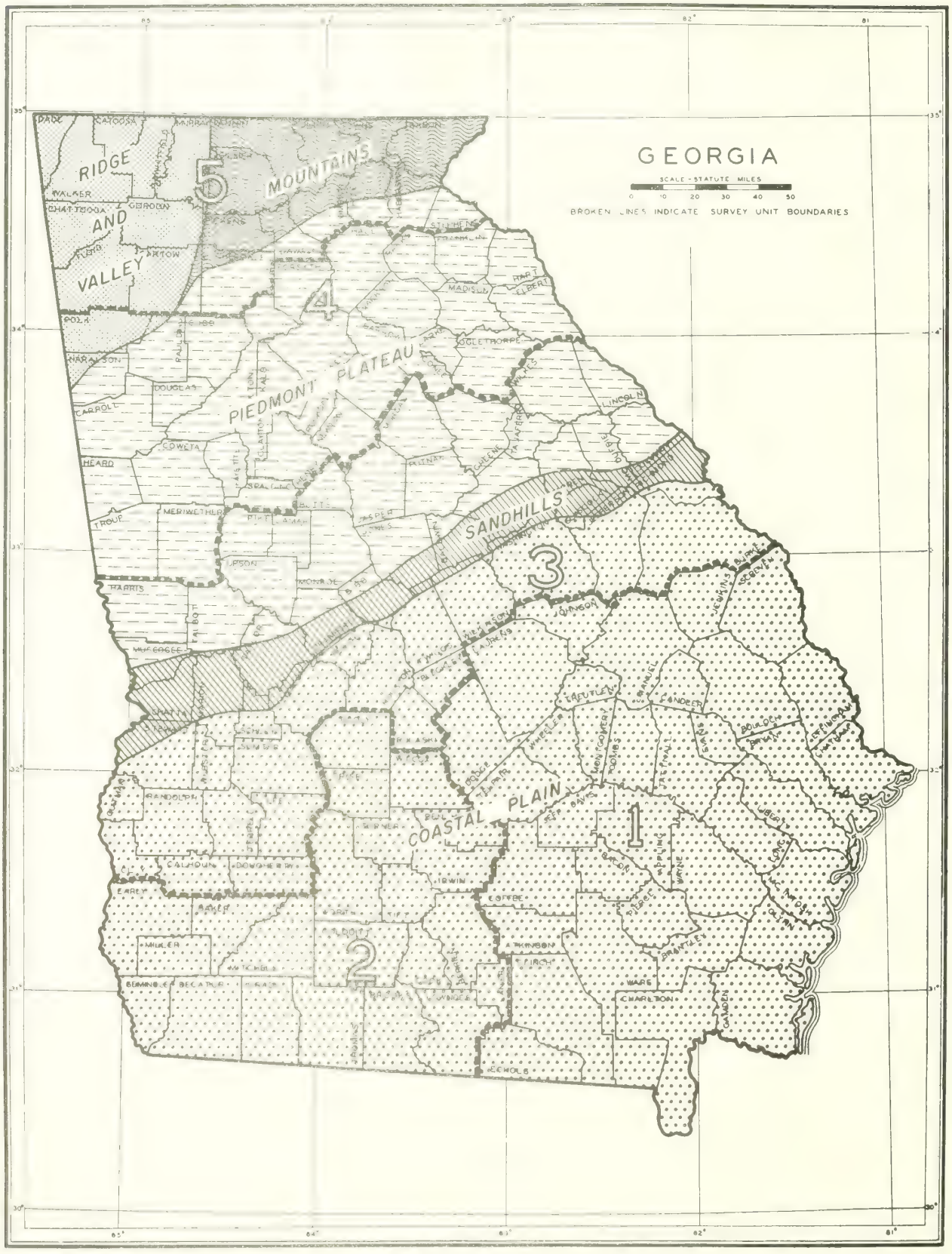


Figure 2.--Geographic provinces and forest survey units in Georgia.

SUPPLY AND USE OF HARDWOODS

Forests of central and north Georgia contain a far greater volume of hardwoods than present industries can possibly use. Hardwood trees contain 71 million cords (table 1), or 59 percent of the total volume including cull timber. Yet they provide only a fifth of the annual cut--nearly all of it from growing stock. [1] Forty-two million cords, or 59 percent of this volume, is growing stock. Only 29 percent of the gum and yellow-poplar, [2] and 24 percent of the oak and hickory [3] is in trees large enough and of high enough quality to make saw logs (fig. 3). Hardwood sawtimber trees, which include trees 11.0 inches and larger having at least one merchantable 12-foot saw log in them, contain 8.4 billion board-feet, or about half the total softwood and hardwood board-foot volume.

Table 1.--Net volume of all hardwood timber by species and class of material

Species	Saw-log portion		Upper stem	Pole timber	Cull timber [1]	Total	
	Million bd. ft.	Thousand cords	Thousand cords	Thousand cords	Thousand cords	Thousand cords	Percent
Blackgum	1,118.0	2,525	639	2,080	3,009	8,253	11.6
Sweetgum	1,331.4	3,007	757	3,448	2,984	10,196	14.4
Yellow-poplar	914.4	2,006	498	1,460	1,484	5,448	7.7
Soft maple	241.1	555	129	704	2,174	3,562	5.0
Other soft hdwds.	167.8	383	91	373	910	1,757	2.5
Total soft hdwds.	3,772.7	8,476	2,114	8,065	10,561	29,216	41.2
White & swamp chestnut oak	721.0	1,567	419	1,786	1,604	5,376	7.5
Other white oaks	649.0	1,404	359	1,699	3,507	6,969	9.8
Northern red & shumard oak	409.7	845	221	280	826	2,172	3.1
Other red oaks	1,547.7	3,360	886	3,206	5,731	13,183	18.6
Hickory	717.7	1,592	391	1,372	2,238	5,593	7.9
Ash	185.6	443	101	598	707	1,849	2.6
Other hard hdwds.	422.7	961	244	1,323	4,106	6,634	9.3
Total hard hdwds.	4,653.4	10,172	2,621	10,264	18,719	41,776	58.8
All hdwds.	8,426.1	18,648	4,735	18,329	29,280	70,992	100.0

1/ Includes limb volume of hardwood sawtimber trees and volume of noncommercial species.

1/ Growing stock is volume in trees 5.0 inches and larger which are either now suitable for saw logs or show promise of becoming suitable for saw logs when they become large enough.

2/ Includes a small amount of soft maple and other soft hardwoods.

3/ Includes a small amount of other hard hardwoods.

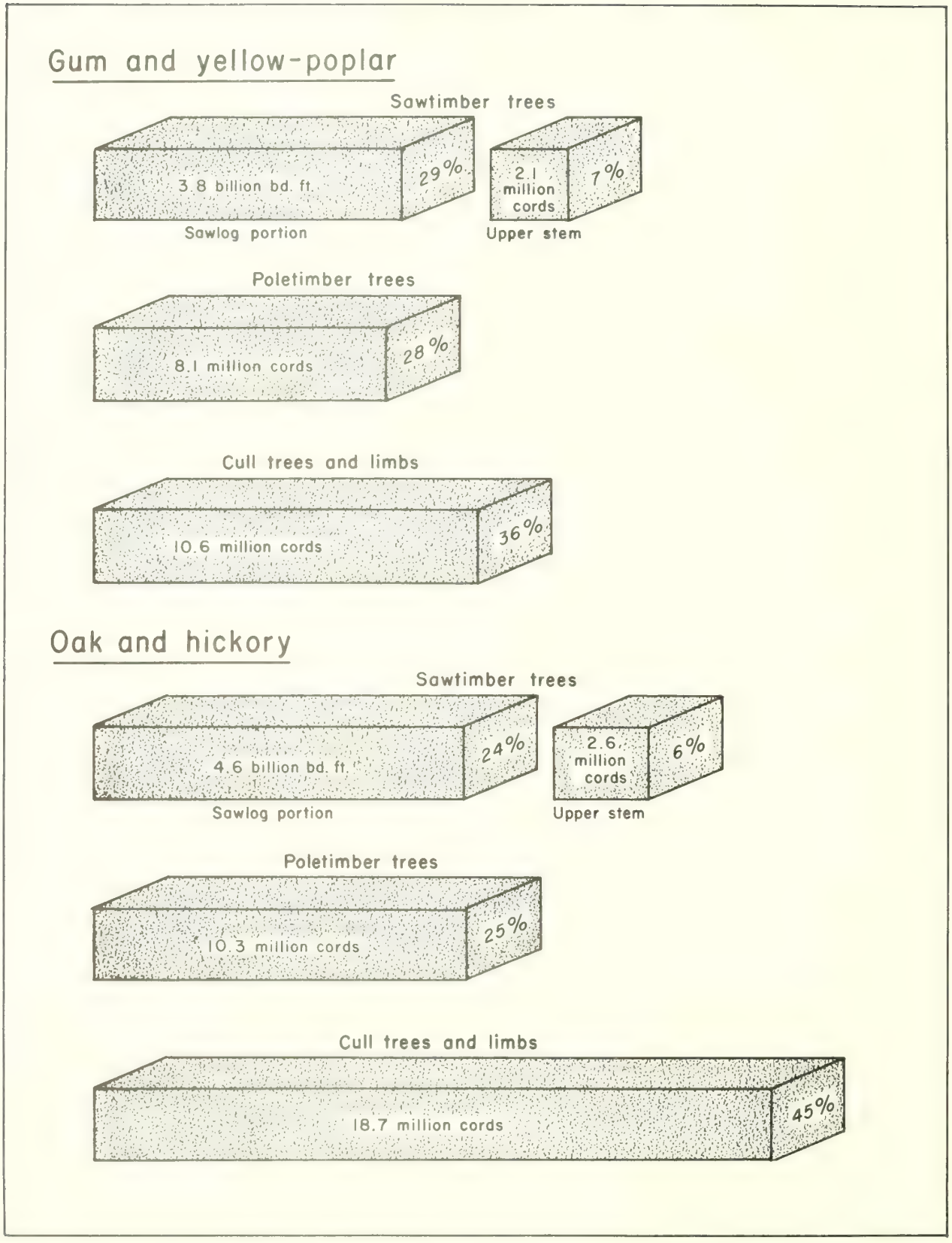


Figure 3.--Net volume of hardwood timber by species group and class of material.

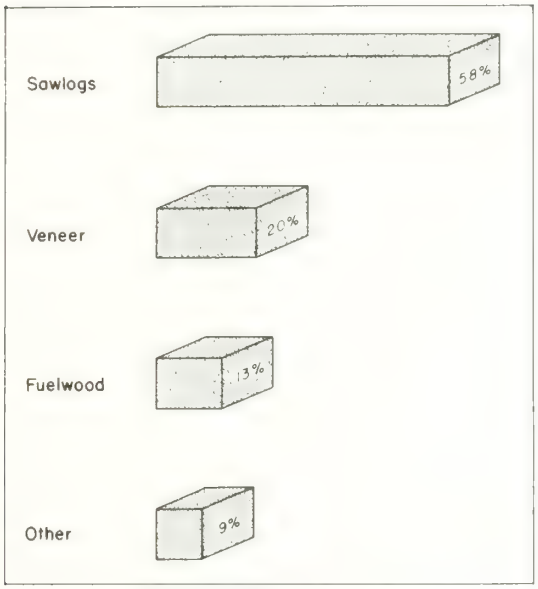


Figure 4.--Annual cut of hardwood growing stock by product.

Eighty-five percent of the annual hardwood cut comes from sawtimber trees. Sawmills and veneer plants use about four-fifths of the hardwood timber cut, and a fifth is used by veneer plants (fig. 4). Roughly, two-thirds of the hardwood lumber sawn is used for the manufacture of secondary products; the remainder is used for railroad ties and construction. The leading secondary products are containers, flooring, and furniture. By far the biggest share of the hardwood veneer is made into containers, including fruit and vegetable containers and packing cases. Less than 10 percent is used by furniture manufacturing plants. 4/

The relationship between standing hardwood sawtimber volume in central and north Georgia and wood used in manufacture in the entire state in 1948 provides some indication of the intensity of use by species. The ratio between wood used in manufacture and standing sawtimber is three times as great for gum and yellow-poplar as for oak and hickory. Yellow-poplar has the highest ratio, followed by ash, sweetgum, and blackgum. Yellow-poplar, which makes up 11 percent of the hardwood sawtimber volume, provided a fourth of the hardwood used in manufacture. Even soft maple, which is one of Georgia's least desirable species, showed a heavier use in relation to the supply than the oaks. The least used species in relation to the supply is hickory.

The heaviest demand is for large sawtimber, or trees 15.0 inches and larger, especially the large gum and yellow-poplar trees (fig. 5). About half the sawtimber volume is in large sawtimber trees, and 41 percent of this in gum and yellow-poplar. In contrast, three-fourths of the annual hardwood sawtimber cut comes from large sawtimber, two-thirds of this from gum and yellow-poplar.

In addition to the sawtimber, there are 18 million cords in hardwood trees 5.0 to 11.0 inches (poletimber) which are expected to qualify as sawtimber when they become large enough.

The relationship between current annual cut and growth is shown in figure 6 for the two species groups, gum and yellow-poplar, and oak and hickory.

4/ Wood used in manufacture, 1948, U. S. Dept. Agr. Forest Resource Rpt. No. 2, 66 pp., illus. 1951.

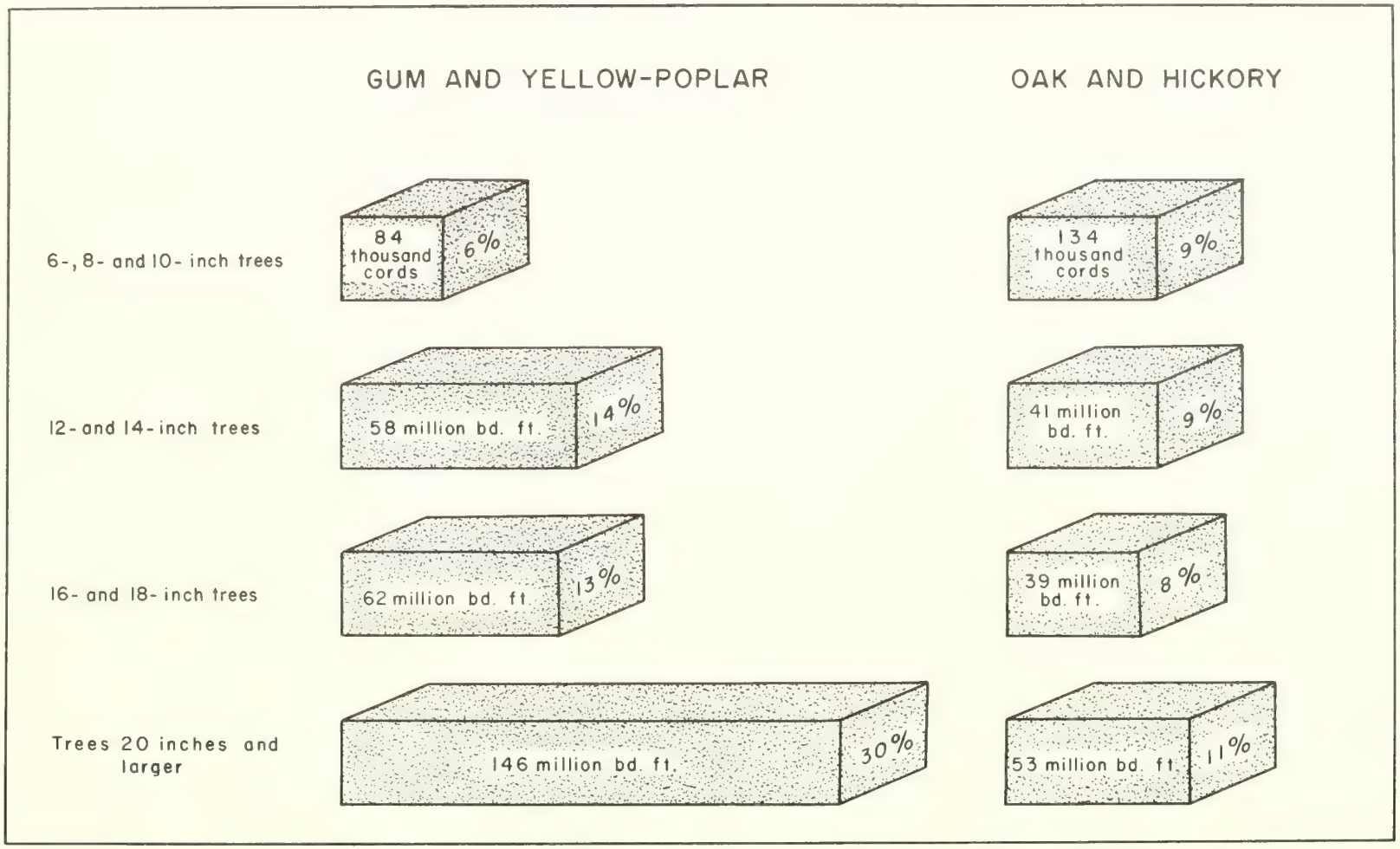


Figure 5.--Volume of hardwood growing stock cut annually, by size and species group. Forty-one percent of the hardwood timber cut comes from trees 20 inches and larger.

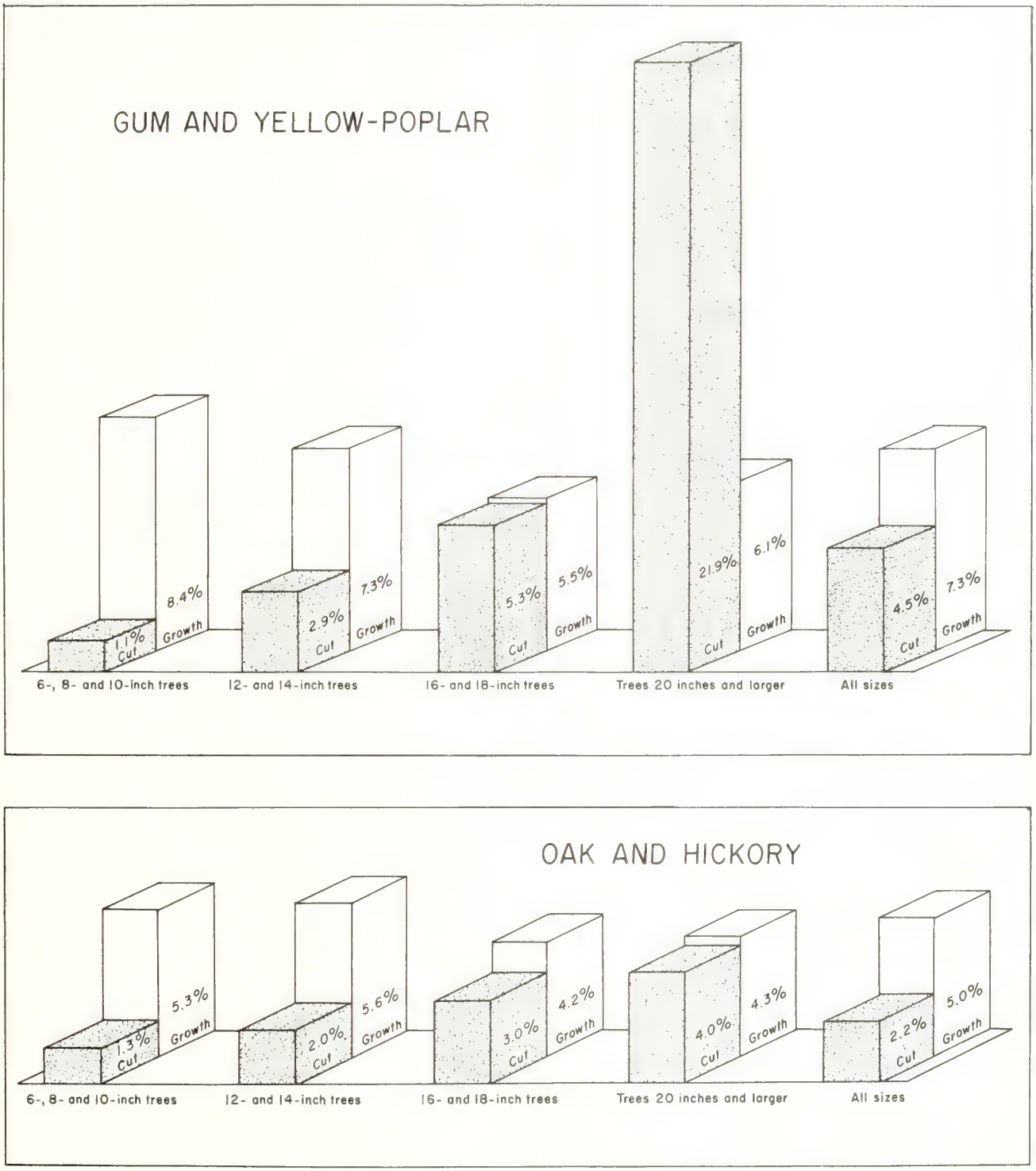


Figure 6.--Percent of growing stock cut annually and growth rate, by size of timber.

Volume in material not of growing stock quality amounts to 29 million cords--most of it in trees which, because of rot, crook, or excessive limbiness, will not qualify as sawtimber. Included is a small volume in limbs of sawtimber trees. Except for a small amount cut for fuelwood, practically no use is being made of this kind of timber.

In 1954, only 8,300 cords of hardwoods, excluding dead chestnut, were cut for pulpwood--less than one percent of the total pulpwood cut in Survey Units 3, 4, and 5. While this was an increase over the 5,000 cords cut in 1953, it was less than the 10,000 cords cut in 1952.

Hardwood cutting in relation to growth in most parts of central and north Georgia is light. At the time the Forest Survey was in progress, the cut of gum and yellow-poplar exceeded the average growth rate in only 26 out of the total 102 counties. Hardwoods were being cut heaviest in the areas bordering the principal rivers in the southern part of Survey Unit 3. An especially heavy cut of gum and yellow-poplar was under way in the upper reaches of the Flint River in the west central part of the State (fig. 7).

Oak and hickory were being cut the heaviest in the northern part of the State, but in only a few counties was the cut in excess of growth.

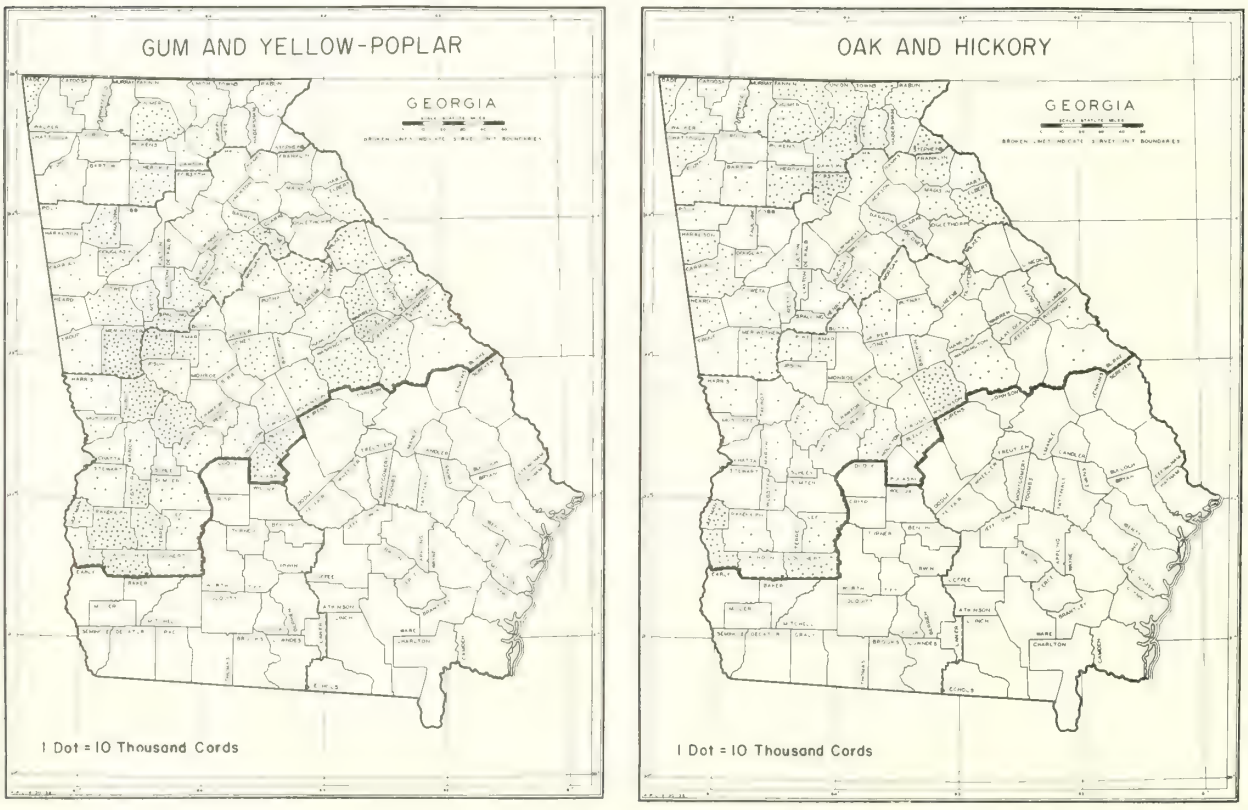


Figure 7.--Average annual volume of hardwood growing stock cut by county.

TREND IN THE HARDWOOD TIMBER SUPPLY

In the 18 years between surveys in central and north Georgia, the volume of hardwood growing stock, i.e., volume in sound trees 5.0 inches and larger, increased by 3 percent. However, not all hardwoods of all sizes increased; the increase was due mainly to large increases in small timber, especially oak and hickory. Gum and yellow-poplar growing stock dropped 9 percent, while oak and hickory increased 15 percent. A drop of 24 percent in gum and yellow-poplar sawtimber resulted in a 10-percent decrease in all hardwood sawtimber in spite of the 6-percent increase in oak and hickory sawtimber.

Large gum and yellow-poplar timber has borne the brunt of the cutting between surveys. The volume in 16- and 18-inch gum and yellow-poplar trees decreased 27 percent, and the volume in trees 20 inches and larger dropped nearly 60 percent. In recent years, growth of the 16- and 18-inch trees has overtaken the cut, but the volume in trees 20 inches and larger is dropping even faster now than during the past 18 years (fig. 8). The current annual cut of this larger timber is 22 percent of the growing stock--more than three times the growth.

Between surveys, growth of 16- and 18-inch oak and hickory was just about enough to replace the cut (fig. 9). The volume in 20-inch and larger oak and hickory declined, but not nearly as much as gum and yellow-poplar.

The volume of hardwood poletimber increased by about one-fourth between the two surveys. The increase in small gum and yellow-poplar sawtimber was considerably less, but that of small oak and hickory sawtimber was almost as great as poletimber. At present, both poletimber and small sawtimber, all hardwood species, are increasing at an even faster rate than in the past, as shown in figures 8 and 9.

There is two-thirds again as much volume in cull trees now as there was at the time of the first survey. All the increase was in sound cull timber, especially gum and yellow-poplar. The volume in rotten culls actually declined. There is now three and a half times as much volume in gum and yellow-poplar culls 16 inches and larger as in 1936. Assuming that sound cull trees are growing at approximately the same rate as the growing stock, the volume in sound cull trees is increasing at the rate of about 4 percent a year. The trend in the general quality of hardwood timber is down. In 1936, 16 percent of the gum and yellow-poplar volume was in cull trees; by 1953, the proportion has increased to 29 percent. The proportion of oak and hickory volume in cull trees increased from 31 to 37 percent during this time.

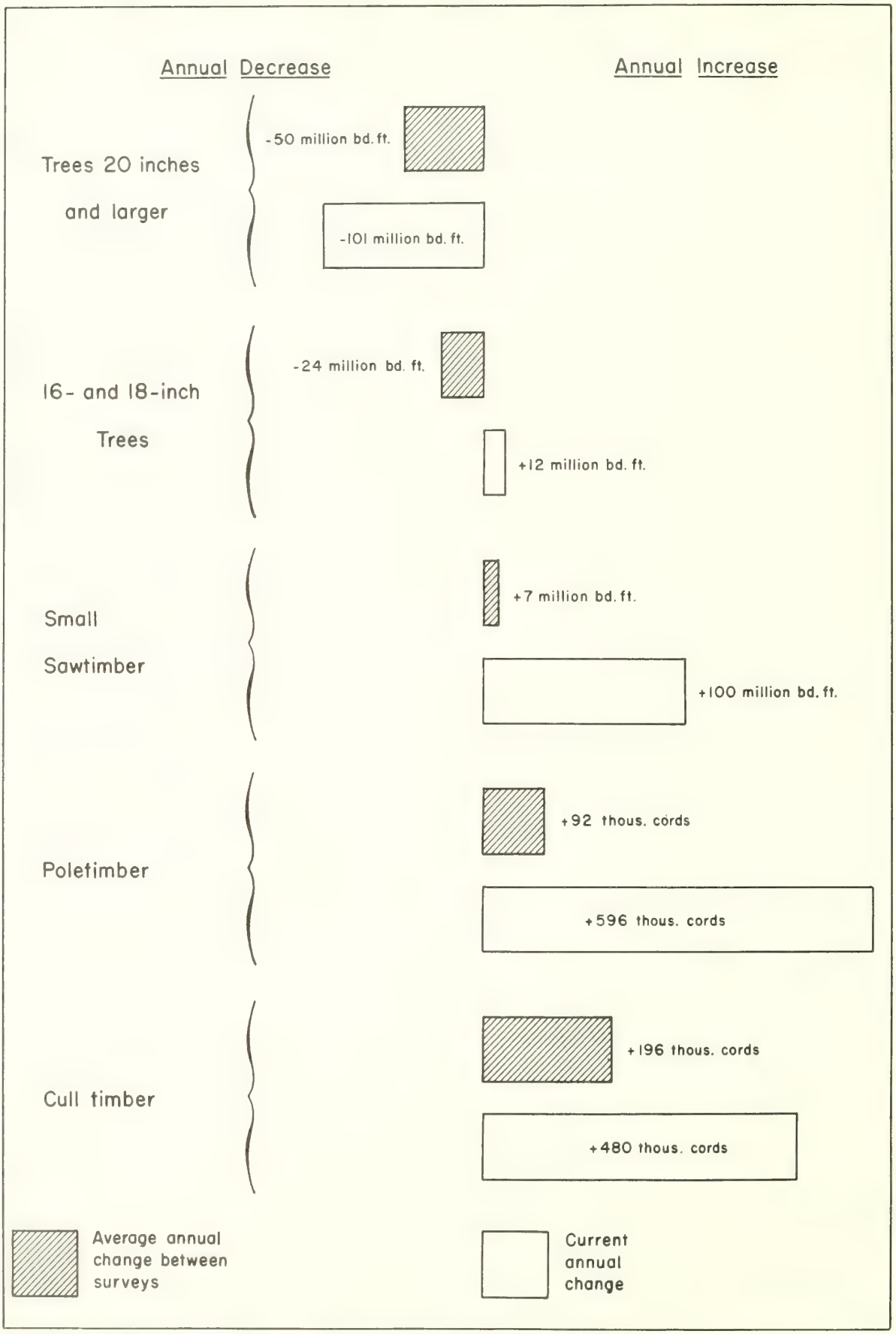


Figure 8.--Change in volume of gum and yellow-poplar.

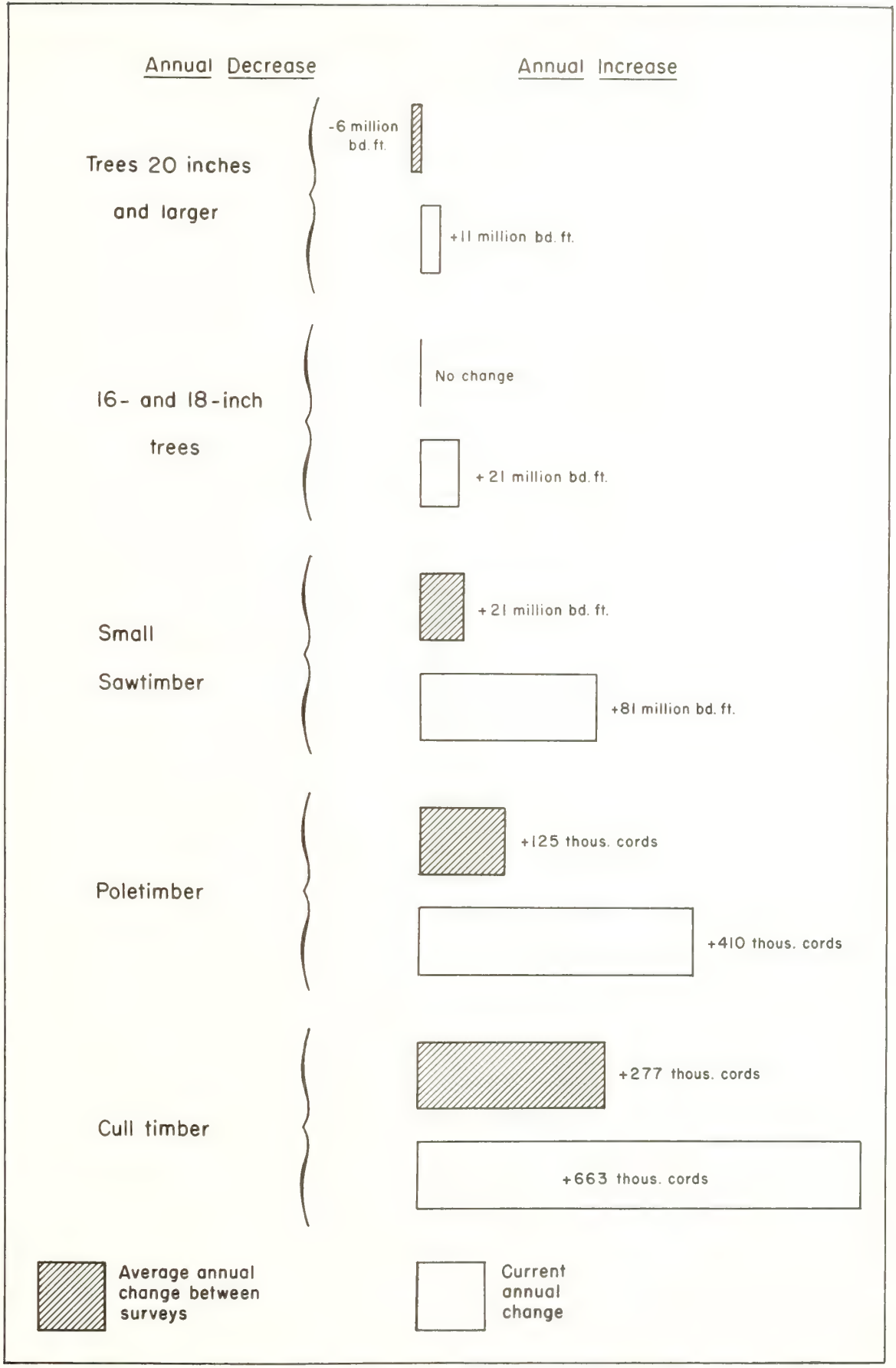


Figure 9.--Change in volume of oak and hickory.

GEOGRAPHIC DISTRIBUTION OF HARDWOODS

Figures 10 through 12 show distribution of total net cubic foot volume of the principal hardwood species, including net volume in cull trees, by county. Figure 13 shows the distribution of large and small sawtimber volume for the two principal groups of hardwood species, and figure 14 shows the distribution of hardwood pole timber and cull timber volume for the two hardwood species groups.

The southern part of the region, especially the river bottoms bordering the major streams, contains most of the gum volume. The largest share of oak volume, on the other hand, is concentrated in the northern part of the State, especially in the mountains. The other principal hardwood species, including yellow-poplar, soft maple, and hickory, are distributed fairly evenly throughout the State.

Distribution of hardwoods by size of timber follows much the same general pattern except that the smaller timber appears to be more evenly distributed than large timber. Thus, areas deficient in small sawtimber or poletimber are not as evident as areas deficient in large sawtimber.

About 40 percent of the total hardwood volume is in cull trees. Cull timber averages 4.6 cords per acre of hardwood type; however, in individual counties the volume of cull per acre goes as high as 16 cords. Several counties in the northern section have more than 10 cords of cull per acre. The quality of the timber is especially low in the northwestern ridge and valley section. Here a large group of counties have more than 50 percent of the total volume in cull trees. In the central and southwestern parts of Unit 3, the quality of the hardwood timber is better than average. A number of counties in these sections have less than a third of the total hardwood volume in cull trees.

A large share of the cull volume, practically all of it oak and hickory, is concentrated in the northern section. Elsewhere, cull volume of hardwoods is fairly evenly distributed.

OUTLOOK FOR HARDWOOD MANAGEMENT

Land Suitable for Growing Hardwoods

A large share of the forest land is capable of growing good quality hardwoods. Nearly 90 percent of the forest land now supporting hardwood types, or 4 million acres, is capable of growing hardwoods with at least two 16-foot saw logs in them; over a third will grow hardwoods with three or more saw logs (table 2). Also, there are nearly 4 million acres of pine and oak-pine types on good sites capable of growing good-quality hardwoods. Some of these best sites are probably better suited to growing hardwoods than pine because of the difficulty of perpetuating the pine in face of the strong hardwood competition. Growing good-quality hardwoods in mixture with the pine may prove to be the most profitable system of management on a large part of this land. Altogether, it is estimated that about 8 million acres out of the 13 million acres of the forest area in central and north Georgia are capable of growing good-quality hardwoods.

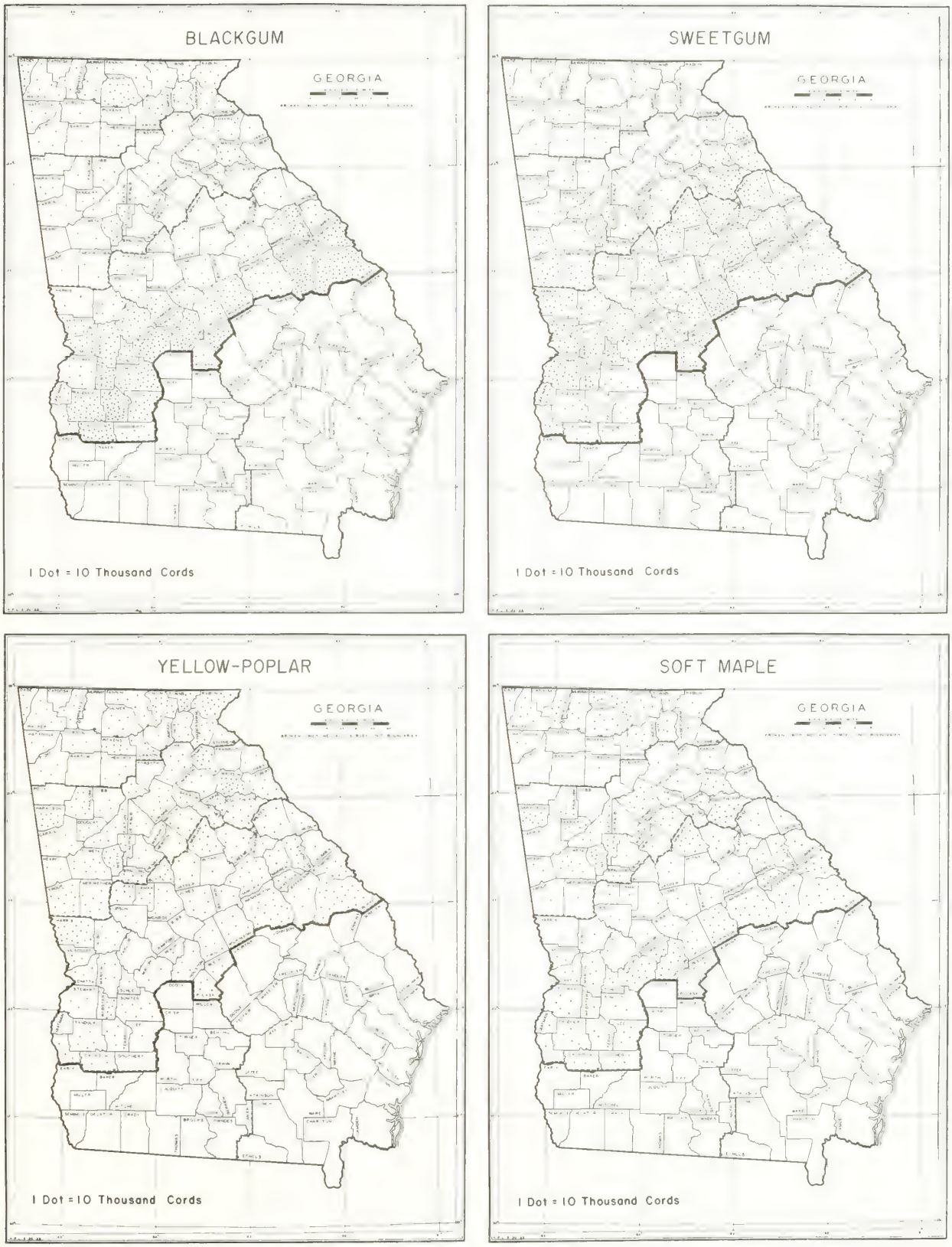
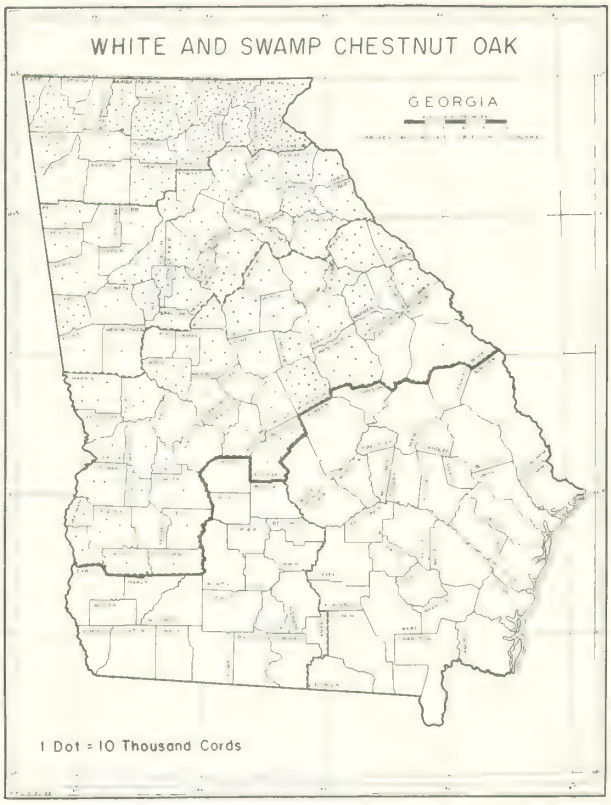
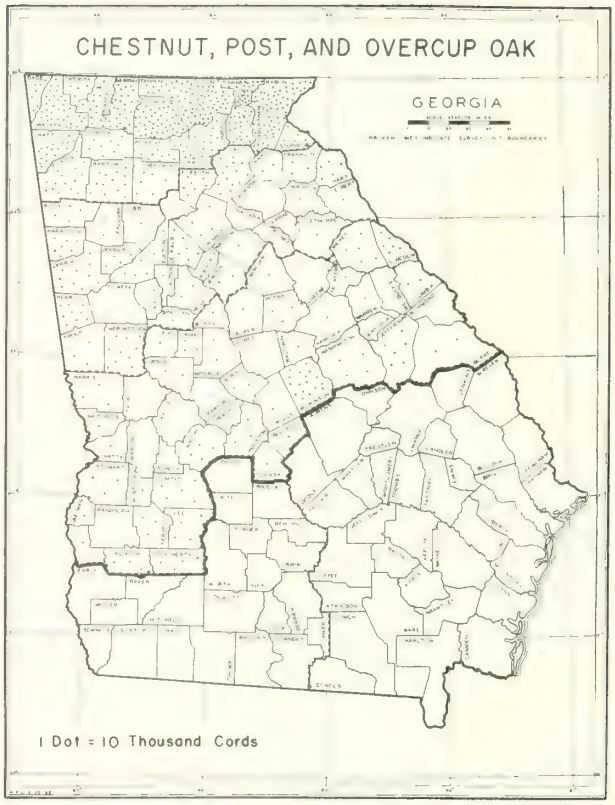
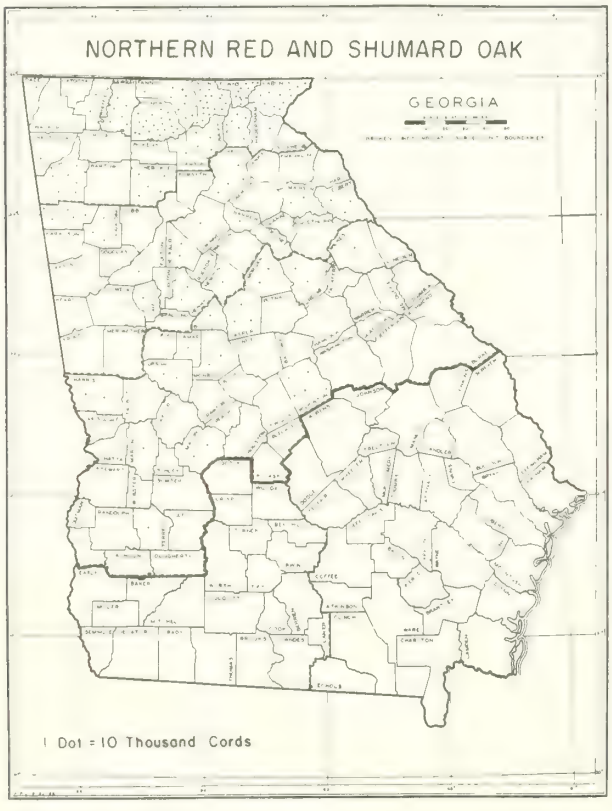


Figure 10.--Distribution of gum, yellow-poplar and soft maple timber.







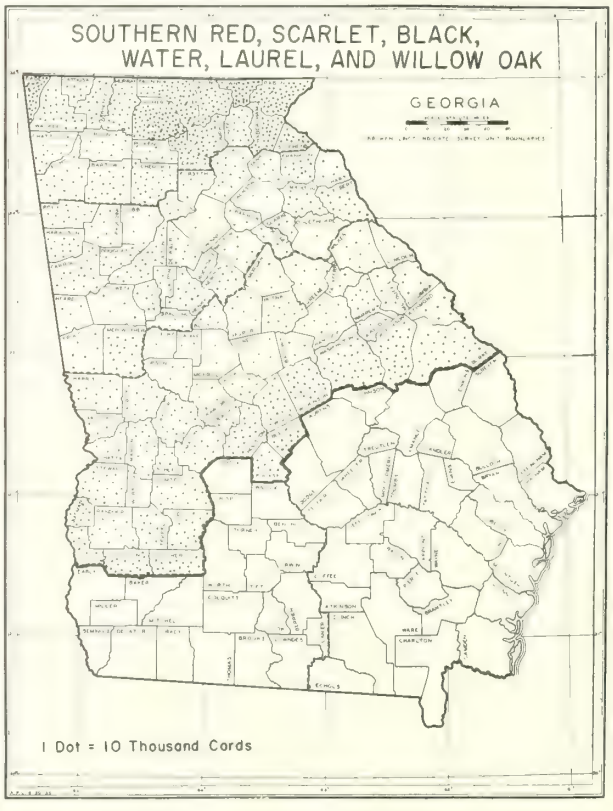


Figure 11.--Distribution of oak timber.

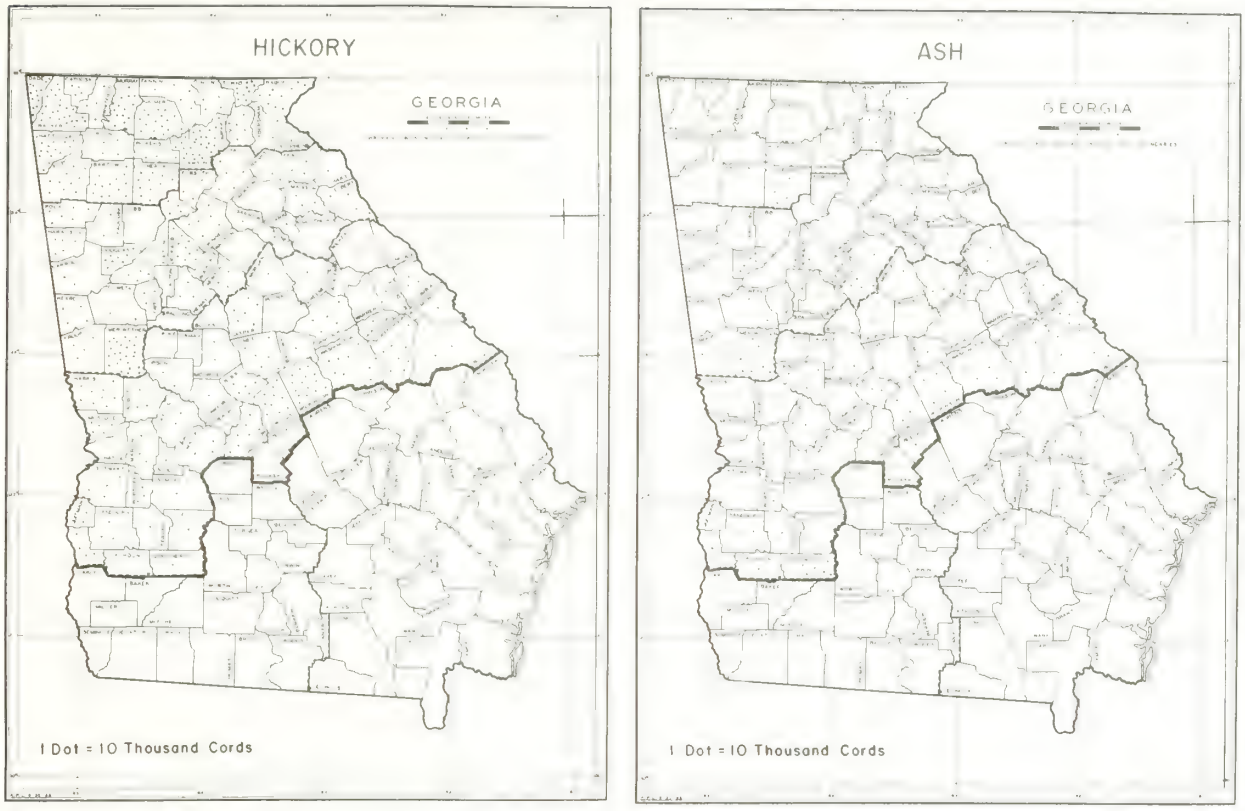


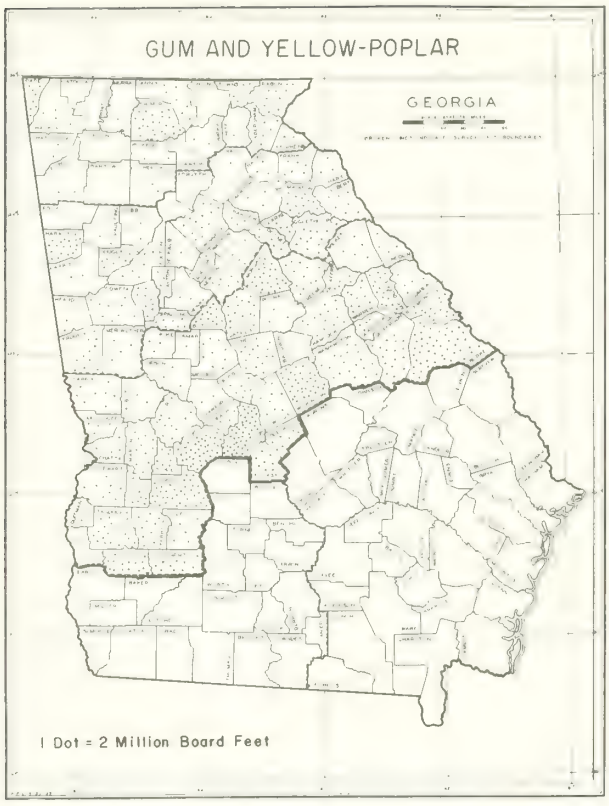
Figure 12.--Distribution of hickory and ash timber.

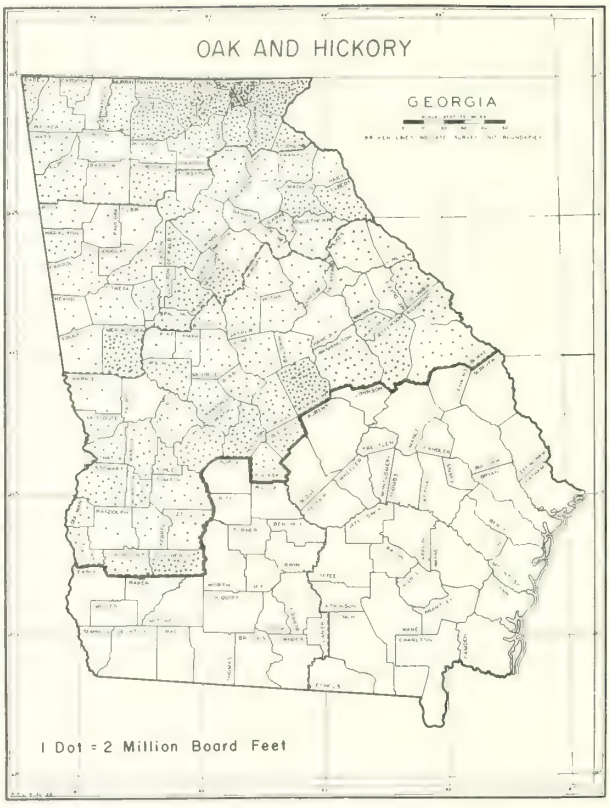
Table 2.--Area of forest types by site quality [1/]

Forest type	Site quality			
	Poor	Fair	Good	Total
	Thousand acres			
Pine	1,428	2,539	3,031	6,998
Oak-pine	399	514	667	1,580
Oak-hickory	317	1,488	759	2,564
Oak-gum-cypress	90	900	924	1,914
Scrub oak	221	8	- -	229
Total	2,455	5,449	5,381	13,285
Percent	18.5	41.0	40.5	100.0

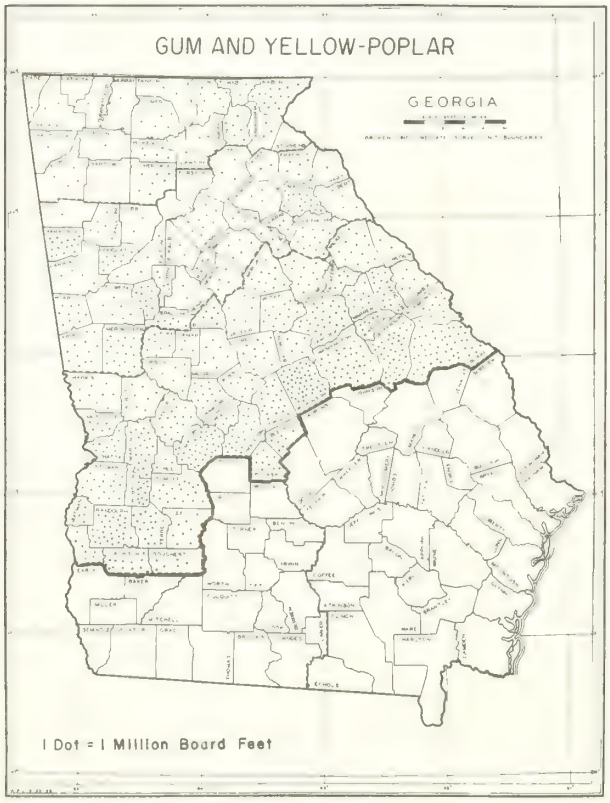
1/ Site quality of pine and oak-pine types is based on the total height of pine at age 50. For loblolly pine and oak-loblolly pine types, an index of 60 or shorter is regarded as poor site, 70 fair site, and 80 and taller good site. For other pine and oak-pine types, a site index of 50 or shorter is considered poor site, 60 fair site, and 70 and taller good site. Site quality of hardwood types is based upon the number of 16-foot saw logs in hardwood trees at maturity. Sites capable of growing hardwoods with three or more saw logs are considered good sites, 2 logs fair sites, and 1 log and less poor sites.

LARGE SAWTIMBER





SMALL SAWTIMBER



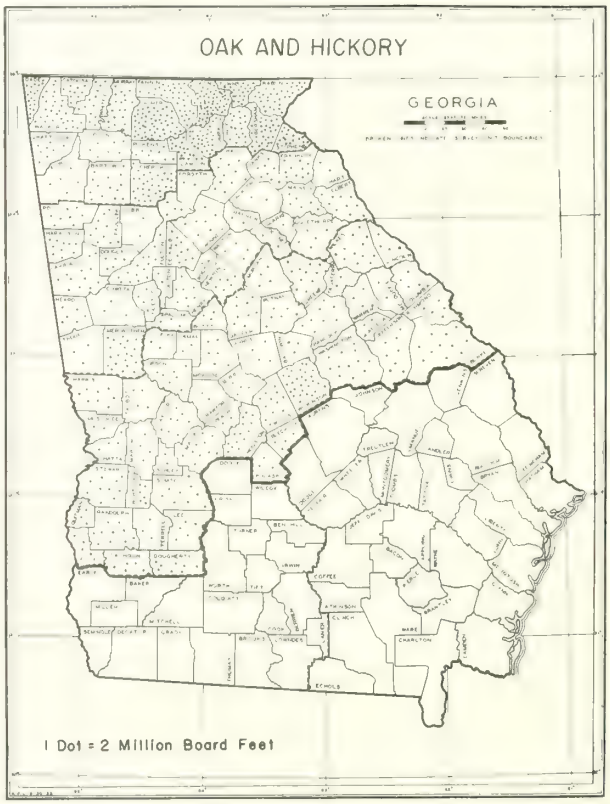
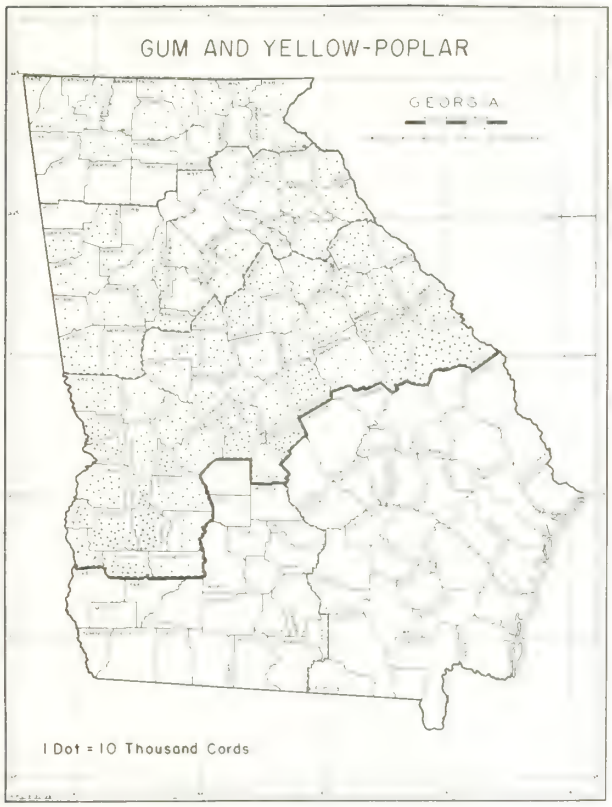
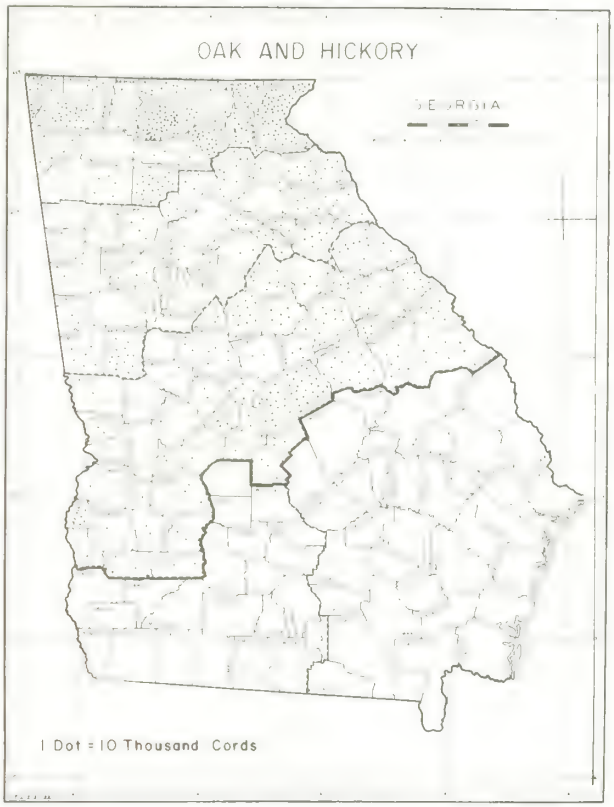


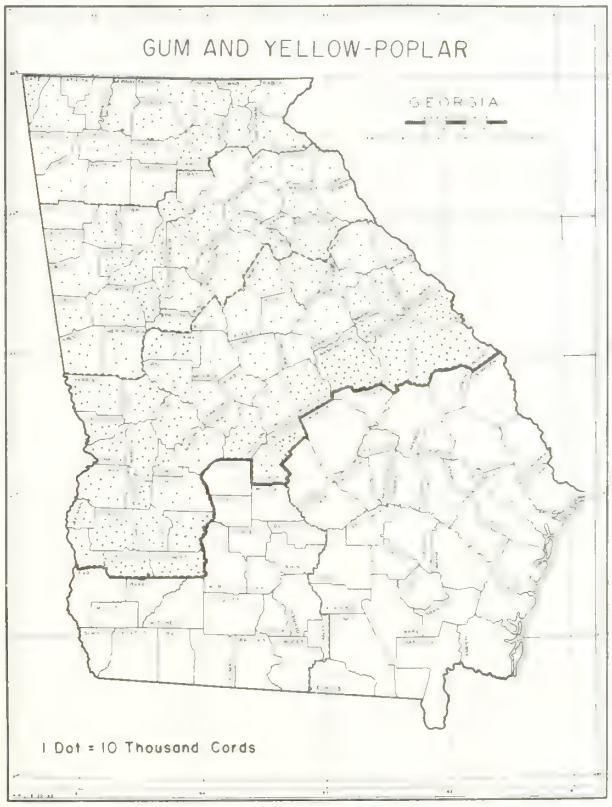
Figure 13.--Distribution of hardwood sawtimber by county.

POLETIMBER





CULL TIMBER



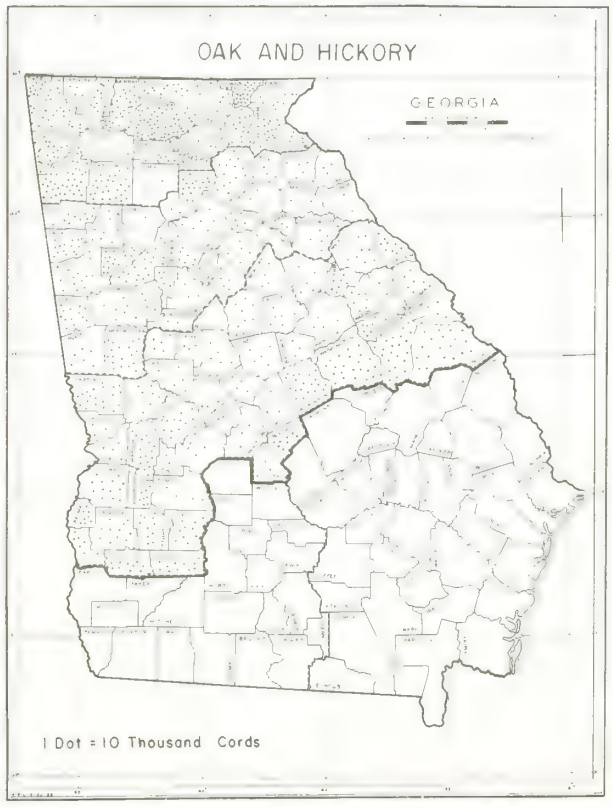


Figure 14.--Distribution of hardwood poletimber and cull timber by county.

In addition, there are about 3 million acres of pine and oak-pine types on fair sites. Some of this area may be capable of growing fair to good-quality hardwoods. Research is needed to determine the hardwood growing potential of these fair pine and oak-pine sites.

Only 2.5 million acres, or 18 percent of the forest area, is clearly unsuited to the production of good-quality hardwoods. This includes 628,000 acres of hardwood type on poor sites. On these areas hardwood trees are short and excessively limby. They seldom contain more than one merchantable saw log, and many never do contain enough merchantable material to qualify as sawtimber. The principal species on 221,000 acres of this poor site area is scrub oak. This land, consisting mainly of deep, coarse sand, once grew longleaf pine, but repeated burning and cutting have eliminated the pine and left only the scrub oak and other low-quality hardwoods.

Equally unsuited to hardwood production are the 1.8 million acres in pine and oak-pine types on poor sites.

Hardwood types on good and fair sites are distributed evenly throughout the region (fig. 15). Hardwood types on poor sites are especially concentrated in the scrub oak of the western Sandhills (fig. 2). The distribution of oak-pine type is about the same on all sites.

Available Growing Stock

While most of the hardwood stands have more than enough trees in them to fully utilize the available growing space, a great many contribute little or nothing to the productivity of the stand. Only about half the hardwood stands have enough trees of growing stock quality, counting seedlings, to fully stock them (table 3). Another 16 percent is well stocked, that is, 70 to 99 percent stocked. Only 53 percent of the total number of hardwood trees 1.0 inch and larger is of growing stock quality (table 4).

Table 3.--Stocking of growing stock on commercial forest land by forest type

Forest type	Stocking class					Total
	0-9	10-39	40-69	70-99	100+	
	Percent					
Oak-pine	3	14	12	14	57	100
Oak-hickory	8	12	18	15	47	100
Oak-gum-cypress	3	13	16	17	51	100
Hardwood types	6	12	17	16	49	100
Pine	4	15	14	12	55	100
All types	5	14	15	14	52	100

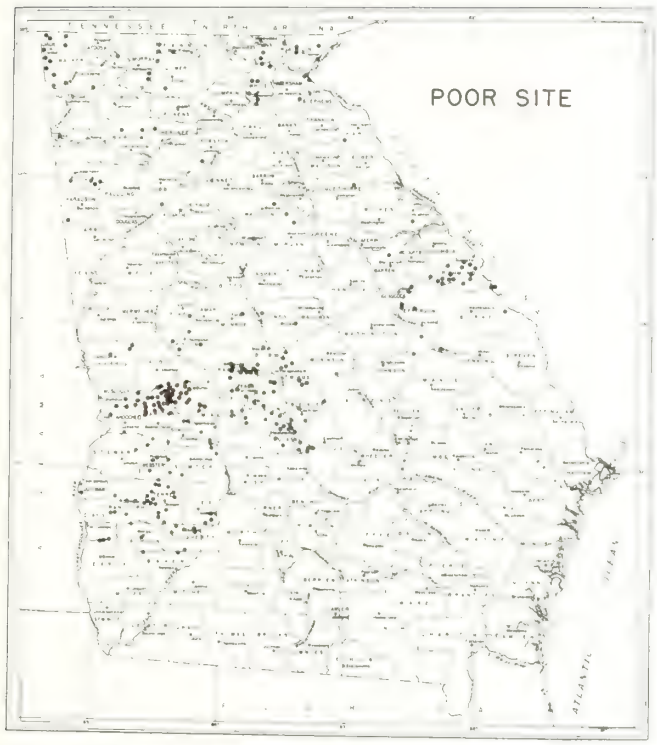


Figure 15.--Distribution of hardwood type forest survey plots by site quality.

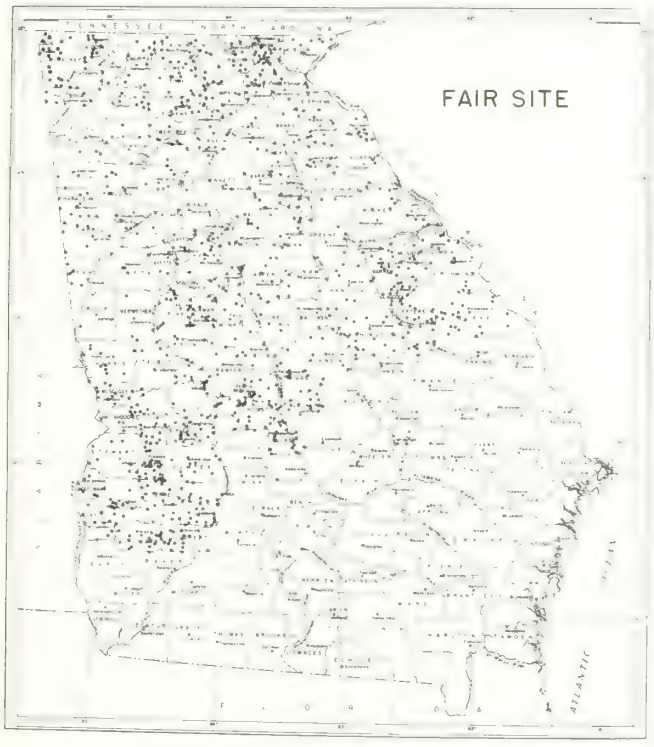


Table 4.--Proportion of the total number of hardwood trees by quality class

Tree quality	Saplings	Poles	Small sawtimber	Large sawtimber	All sizes
			Percent		
Gum and yellow-poplar:					
Growing stock	62	63	71	63	62
Sound culls	37	34	24	26	37
Rotten culls	1	3	5	11	1
All	100	100	100	100	100
Oak and hickory:					
Growing stock	48	49	61	58	48
Sound culls	51	49	35	32	51
Rotten culls	1	2	4	10	1
All	100	100	100	100	100
All hardwoods:					
Growing stock	52	54	65	59	53
Sound culls	47	43	31	30	46
Rotten culls	1	3	4	11	1
All	100	100	100	100	100

Site quality has a profound effect on stocking. Good sites have roughly twice as much basal area of growing stock as poor sites (table 5). Also, the better the site, the larger the proportion of hardwood trees that qualify as growing stock (table 6).

Moreover, the better the site quality, the more closely the distribution of the trees by size class approaches the desirable distribution [5/] on well managed forests. For the most part, the stands are adequately stocked with 2- and 4-inch sound trees. Poor sites are extremely deficient in all trees above 4 inches and have practically no trees above 16 inches on them (figures 16 and 17).

5/ Based on de Liocourt's "q" value of 1.50. This is the ratio in number of trees between size classes. Present pine stands in Georgia have a "q" value of about 2.2; hardwood stands 1.8. Managed selection forests in Switzerland and virgin selection forests in this country have a "q" value of about 1.3.

Table 5.--Average basal area of growing stock by site and type

Forest type	Site quality	Basal area	Percent of full stocking
		Square feet	Percent
Loblolly pine	Poor	26	38
	Fair	32	47
	Good	49	72
Shortleaf pine	Poor	31	46
	Fair	33	49
	Good	50	74
Oak-loblolly pine	Poor	24	35
	Fair	29	43
	Good	58	86
Oak-shortleaf pine	Poor	28	41
	Fair	38	56
	Good	46	68
Oak-hickory	Poor	23	34
	Fair	33	49
	Good	47	69
Oak-gum-cypress	Poor	14	21
	Fair	36	53
	Good	60	89

The size-class distribution in hardwood stands is much more favorable than in oak-pine stands, especially on the better sites. The distribution of basal area by size class on good oak-gum-cypress sites, for example, very closely approaches the desirable.

Growing Stock Quality

Down through the years, loggers have continually removed the more desirable trees from the stands, leaving the less desirable species and individuals. Figure 18 shows the proportion of the total net volume in cull trees for the principal hardwood species and species groups. "Other hard hardwoods" includes the volume of scrub oak.

Table 6.--Basal area per acre of hardwood growing stock and all hardwood 1.0 inch and larger by type and site quality

Forest type	Site quality	Growing stock	All trees	Growing stock
		Sq. ft.	Sq. ft.	Percent
Loblolly pine	Poor	3.78	8.39	45
	Fair	5.30	9.93	53
	Good	9.25	15.19	61
	All sites	6.78	11.78	58
Shortleaf pine	Poor	7.10	16.62	43
	Fair	4.53	11.50	39
	Good	9.87	18.01	55
	All sites	7.37	15.36	48
Oak-loblolly pine	Poor	15.51	29.23	53
	Fair	18.13	32.70	55
	Good	25.22	41.46	61
	All sites	21.30	36.58	58
Oak-shortleaf pine	Poor	18.34	36.37	50
	Fair	24.24	39.92	61
	Good	29.55	44.82	66
	All sites	24.42	40.64	60
Oak-hickory	Poor	18.06	45.00	40
	Fair	30.19	53.94	56
	Good	44.58	71.94	62
	All sites	32.89	58.21	57
Oak-gum-cypress	Poor	11.54	30.88	37
	Fair	33.09	57.80	57
	Good	57.96	85.99	67
	All sites	43.90	69.89	63

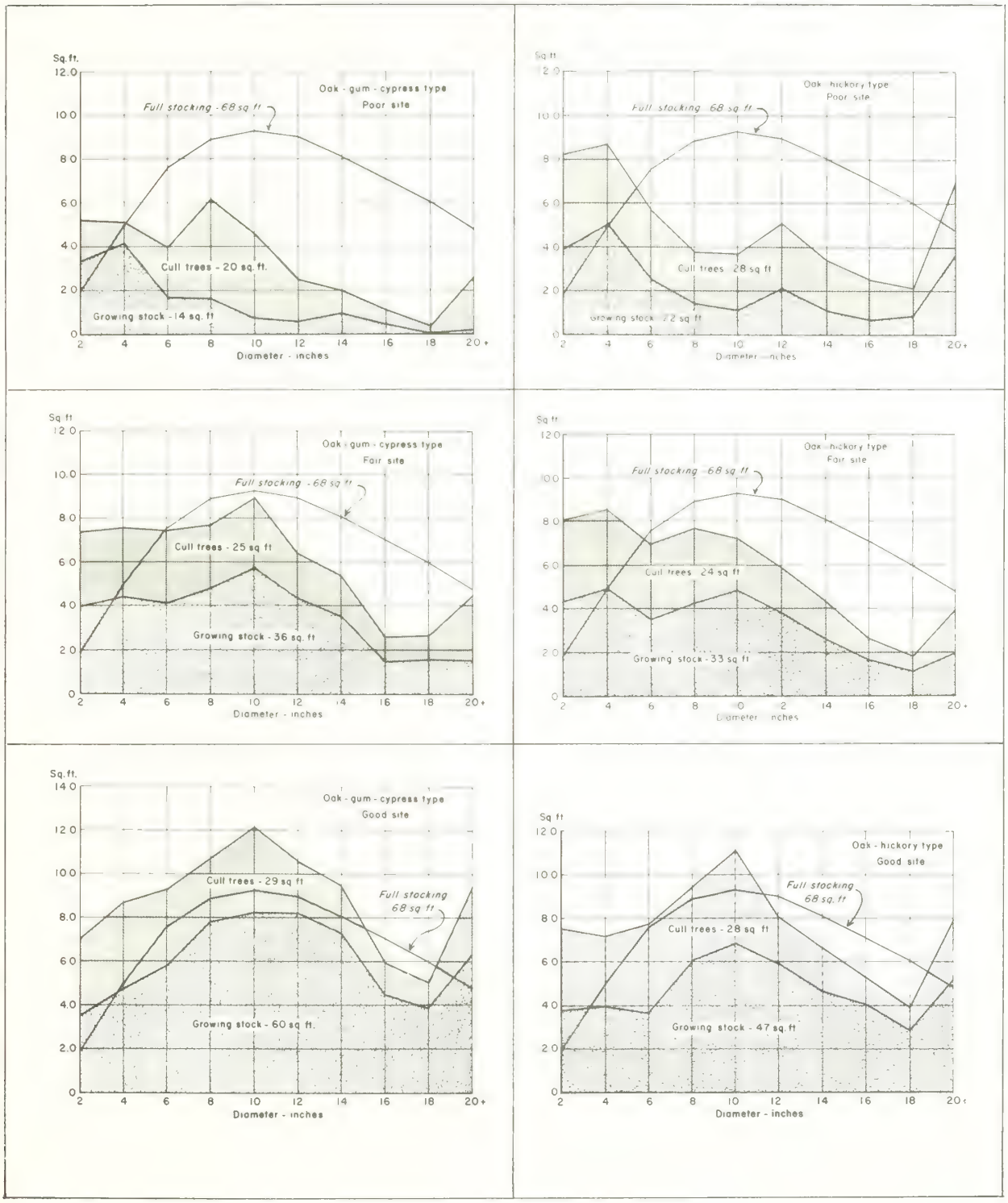

Sq. ft.
Oak - gum - cypress type
Poor site
Full stocking - 68 sq. ft
Cull trees - 20 sq. ft.
Growing stock - 14 sq. ft
Diameter - inches
Oak - hickory type
Poor site
Full stocking - 68 sq. ft
Cull trees - 28 sq ft
Growing stock - 22 sq ft
Oak - gum - cypress type
Fair site
Full stocking - 68 sq. ft
Cull trees - 25 sq. ft
Growing stock - 36 sq. ft
Oak - hickory type
Fair site
Full stocking - 68 sq. ft
Cull trees - 24 sq ft
Growing stock - 33 sq ft
Oak - gum - cypress type
Good site
Cull trees - 29 sq ft
Full stocking 68 sq. ft
Growing stock - 60 sq ft.
Oak - hickory type
Good site
Full stocking 68 sq. ft
Cull trees - 28 sq ft
Growing stock - 47 sq. ft

Figure 16.--Basal area per acre of trees in oak-hickory and oak-gum-cypress types, by tree quality, size, and site quality.

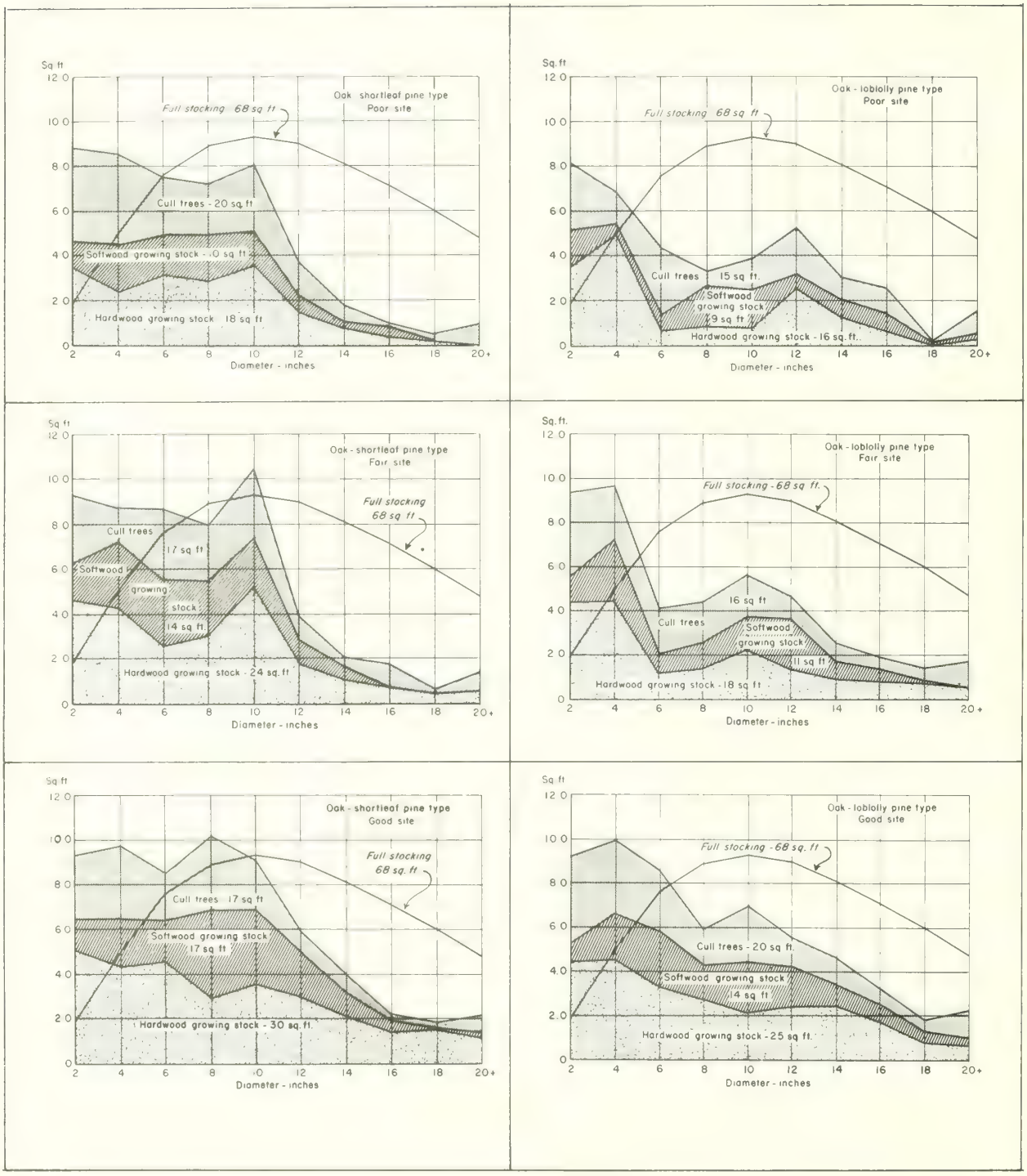

Sq. ft
Oak shortleaf pine type
Poor site
Full stocking 68 sq ft
Cull trees - 20 sq. ft
Softwood growing stock - 10 sq ft
Hardwood growing stock 18 sq ft
Diameter - inches
Oak - loblolly pine type
Poor site
Full stocking 68 sq ft
Cull trees 15 sq ft.
Softwood growing stock 9 sq ft
Hardwood growing stock - 16 sq. ft.
Oak - shortleaf pine type
Fair site
Full stocking 68 sq ft
Cull trees 17 sq ft
Softwood growing stock 14 sq ft
Hardwood growing stock - 24 sq. ft
Oak - loblolly pine type
Fair site
Full stocking - 68 sq ft.
16 sq ft
Cull trees
Softwood growing stock 11 sq ft
Hardwood growing stock - 18 sq ft
Oak - shortleaf pine type
Good site
Full stocking 68 sq. ft
Cull trees 17 sq ft
Softwood growing stock 17 sq ft
Hardwood growing stock - 30 sq. ft.
Oak - loblolly pine type
Good site
Full stocking - 68 sq. ft
Cull trees - 20 sq ft.
Softwood growing stock 14 sq ft
Hardwood growing stock - 25 sq ft.

Figure 17.--Basal area per acre of trees in oak-shortleaf pine and oak-loblolly pine types, by tree quality, size, and site quality.

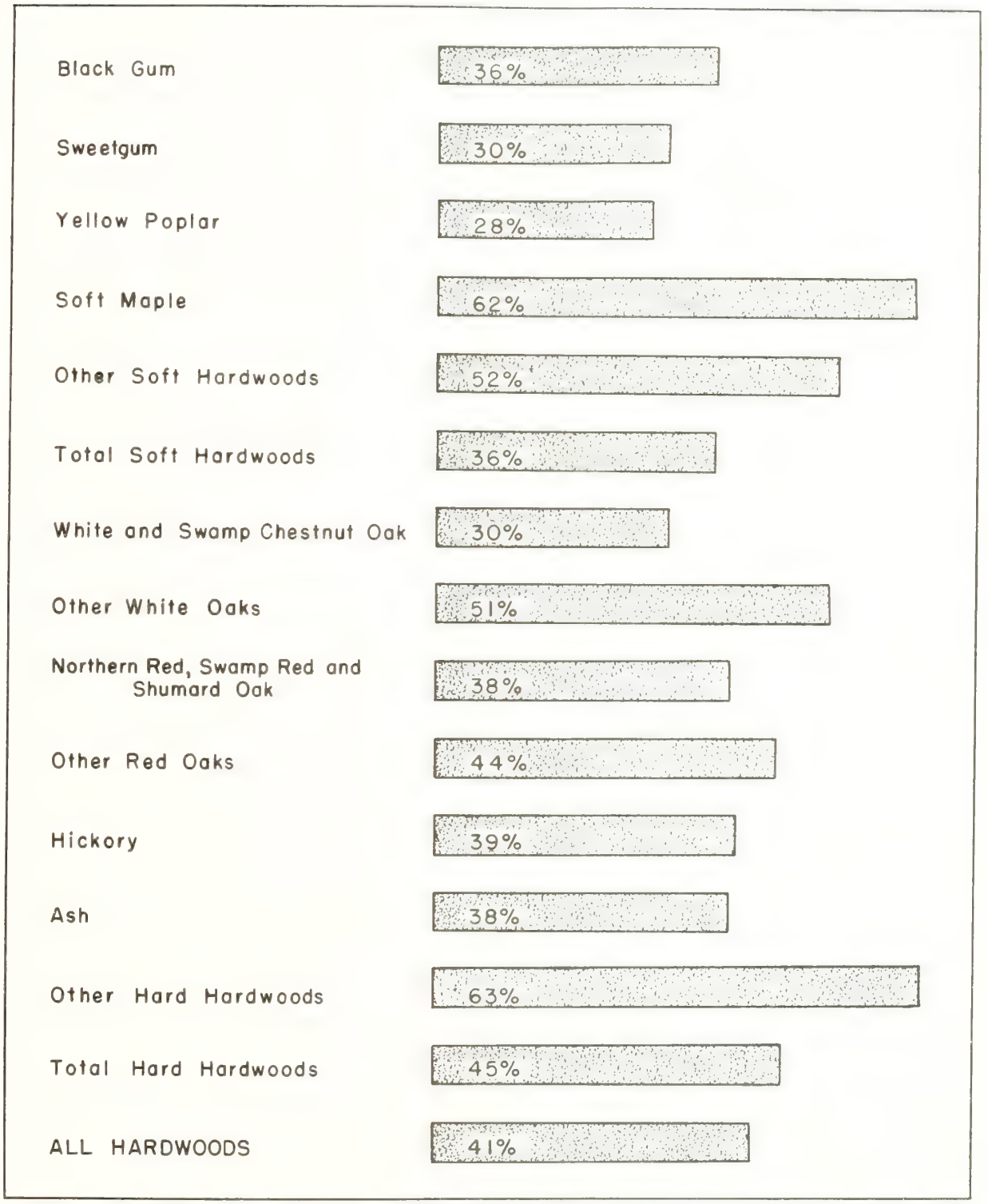


Figure 18.--Percent of the total net hardwood volume in cull trees, by species.

The present growing stock trees are shorter, more defective, and contain fewer high-grade logs than landowners could expect to produce under good forest management. Gum and yellow-poplar large sawtimber have on the average between two and two-and-a-half merchantable saw logs in them; the oaks and hickory are about a half a log shorter (table 7). Between 12 and 15 percent of the board-foot volume in sawtimber is unusable for lumber because of defects (table 8). Log grade quality varies a good deal by species (table 9). The proportion of the volume in grade 1 and 2 logs for large sawtimber ranges from a third or less for such species as soft maple, hickory, and other red oaks to about a half for blackgum, white, and swamp chestnut oak, and ash.

Frequency of Occurrence by Species

A knowledge of the natural tendency for various species to grow in certain combinations and on certain sites provides the landowner with valuable guides to increasing the proportion of the more desirable species in the stand. In the present stands, the frequency and intensity of past cutting, the kind of timber cut, the frequency and intensity of past fires, whether or not the land was cleared for agriculture, the time since the land reverted from farm to forest, and probably other factors have all played a part in determining the occurrence and abundance of the various species. Forests which have not been subjected to major disturbing influences are practically nonexistent in this section of Georgia. Thus, a knowledge of the species composition pattern in these disturbed stands may be even more valuable to the landowner than in natural undisturbed stands.

In the first place, managed stands are disturbed stands; in place of unplanned disturbances, the forest manager merely substitutes carefully controlled disturbances designed to produce a desired effect--such as increasing the amount of pine or yellow-poplar in the stands. Also, it is these disturbed stands that landowners must begin with in improving their forests. The species represented and their abundance in the understory of the present stands on certain sites may provide an important clue as to what individual species should be favored on these sites. Detailed information on the occurrence and abundance of the important hardwood species by forest type, site quality, and size of timber is presented in the charts that follow.

Figures 19 through 22 show the proportion of hardwoods, including cull trees, in the pine and oak-pine stands by diameter class. In general, they show that proportion of hardwoods is greatest among the smallest and largest tree sizes. Figures 23 through 32 show the relative frequency of principal hardwood species by diameter class in stands on various sites.

Table 7.--Average merchantable height by species and size of timber

Species	Pole-timber 1/	Small sawtimber 2/	Large sawtimber 2/
	Feet		
Blackgum	30	29	36
Yellow-poplar	30	32	40
Sweetgum	23	28	37
Soft maple	23	22	26
Other soft hardwoods	24	30	32
White & swamp chestnut oak	24	23	27
Other white oaks	24	21	26
Northern red, swamp red, & shumard oak	24	25	29
Other red oaks	23	25	29
Hickory	24	23	29
Ash	30	23	37
Other hard hardwoods	21	23	27

1/ Height to a 4-inch top inside bark.
2/ Height to the top of the last merchantable saw log.

Table 8.--Average cull percent of large and small sawtimber by species

Species	Small sawtimber	Large sawtimber
	Percent	
Black and tupelo gum	15	13
Yellow-poplar	11	12
Sweetgum	14	12
Soft maple	11	15
Other soft hardwoods	18	12
White & swamp chestnut oak	14	14
Other white oaks	12	13
Northern red, swamp red & shumard oak	9	12
Other red oaks	10	12
Hickory	12	12
Ash	16	20
Other hard hardwoods	13	14

Table 9.--Percent of the total volume of large sawtimber in grade 1 and 2 logs, by species

Species	Large sawtimber
	Percent
Blackgum	47
Yellow-poplar	42
Sweetgum	34
Soft maple	20
Other soft hardwoods	36
White & swamp chestnut oak	50
Other white oaks	45
Northern red, swamp red & shumard oak	39
Other red oaks	32
Hickory	27
Ash	48
Other hard hardwoods	44

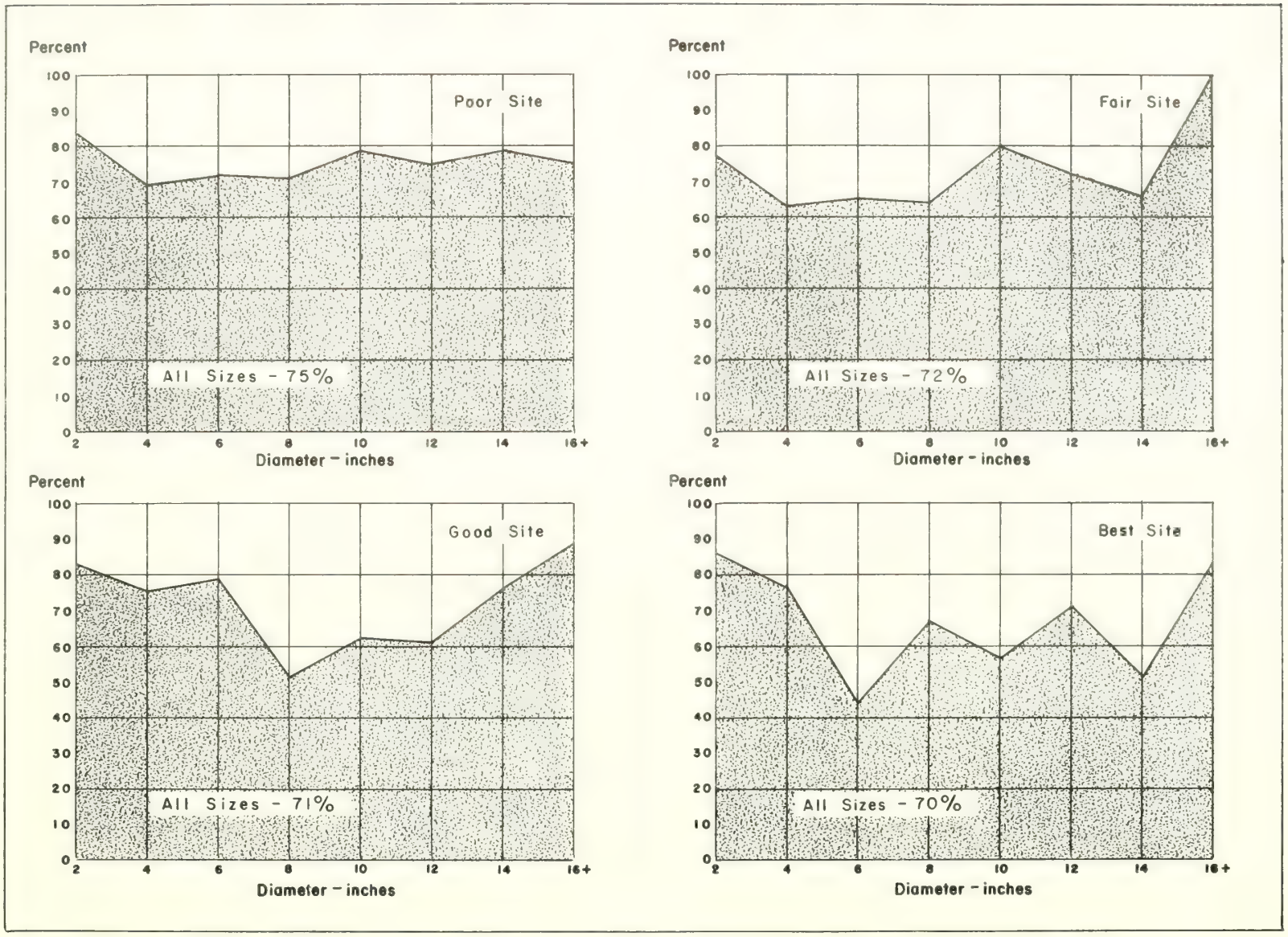


Figure 19.--Hardwood basal area as a percent of total basal area in oak-shortleaf pine type, by site and size of timber.

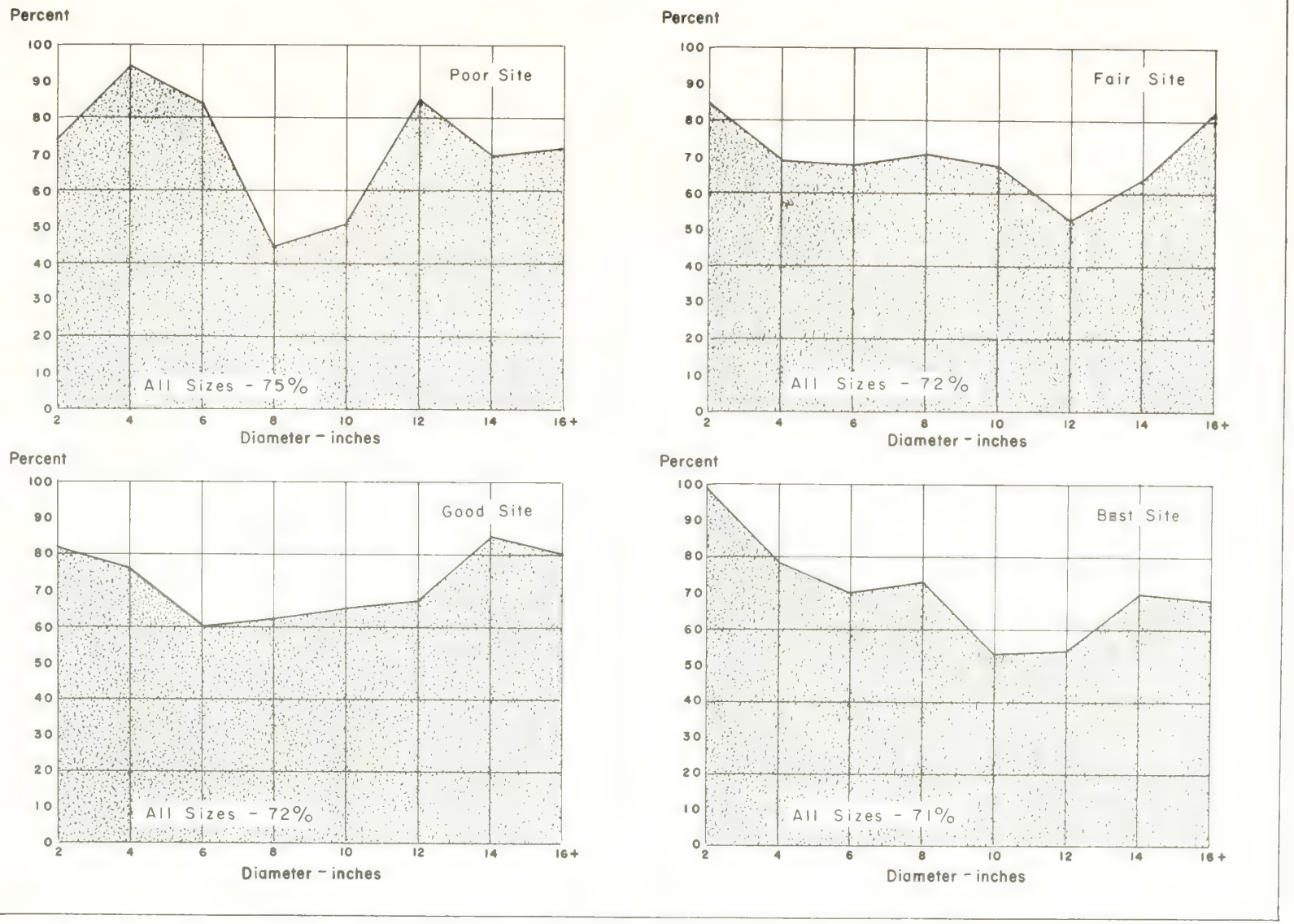


Figure 20.--Hardwood basal area as a percent of total basal area in oak-loblolly pine type, by site and size of timber.

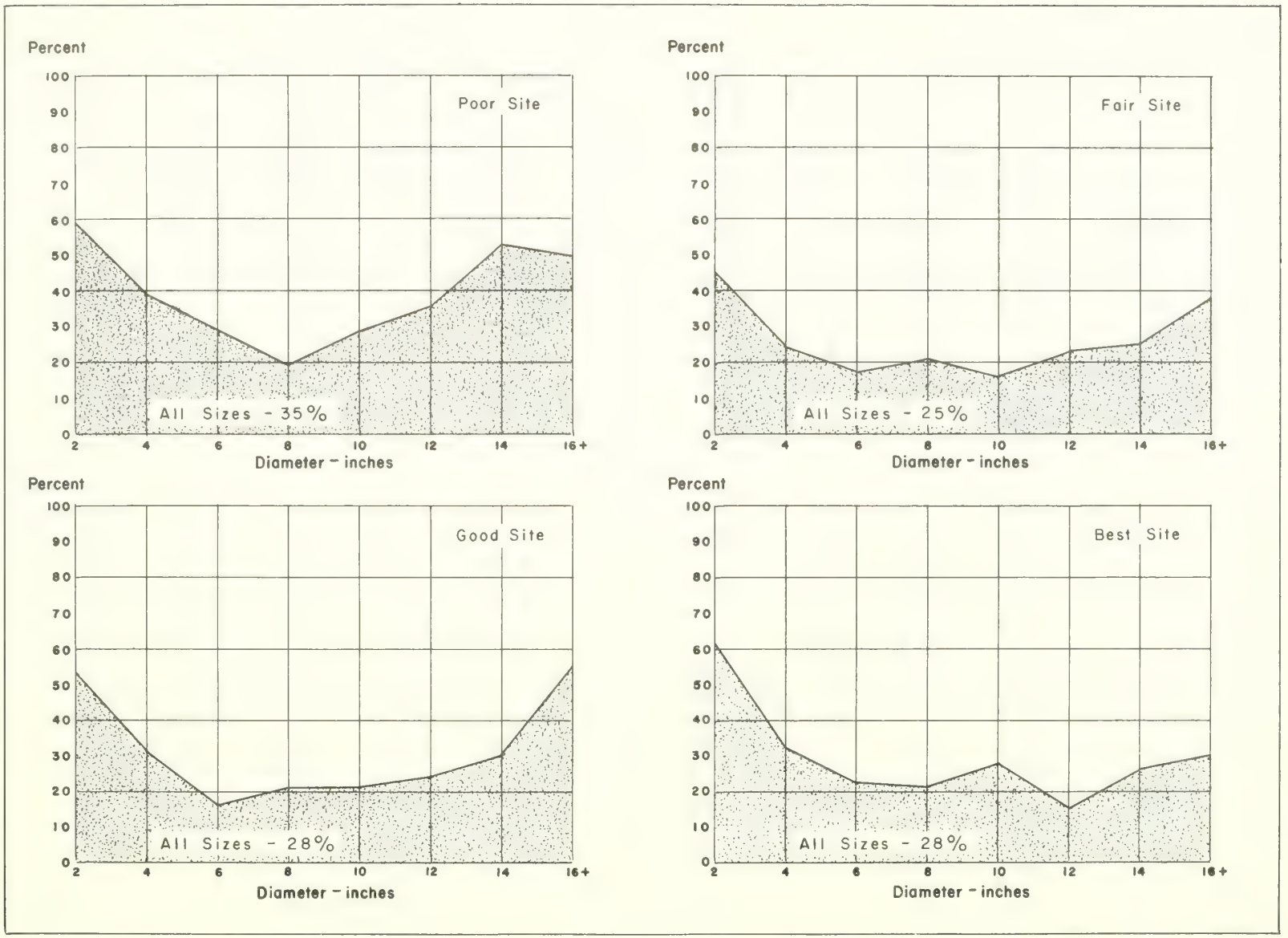


Figure 21.--Hardwood basal area as a percent of total basal area in shortleaf pine type, by site and size of timber.

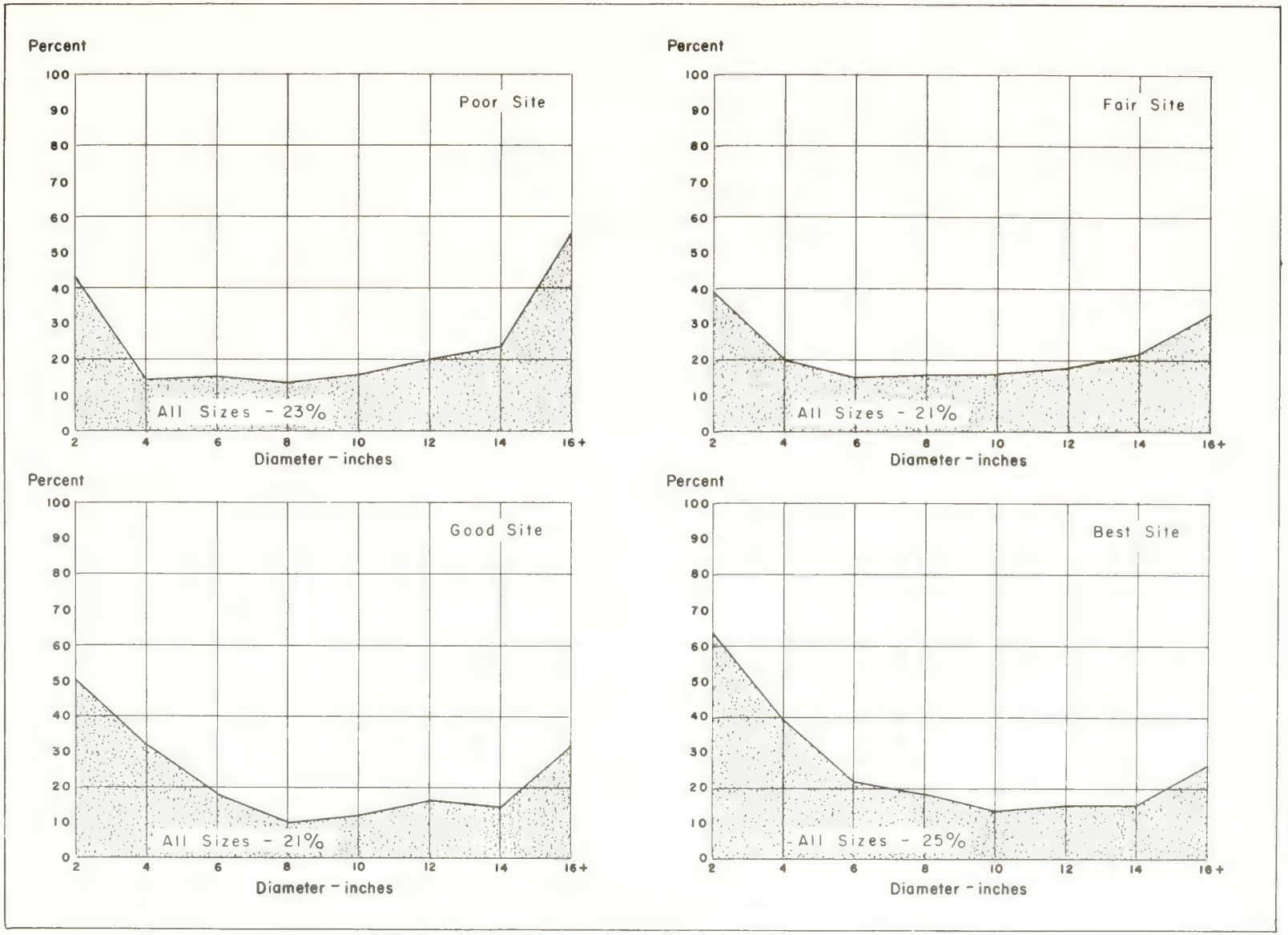


Figure 22.--Hardwood basal area as a percent of total basal area in loblolly pine type, by site and size of timber.

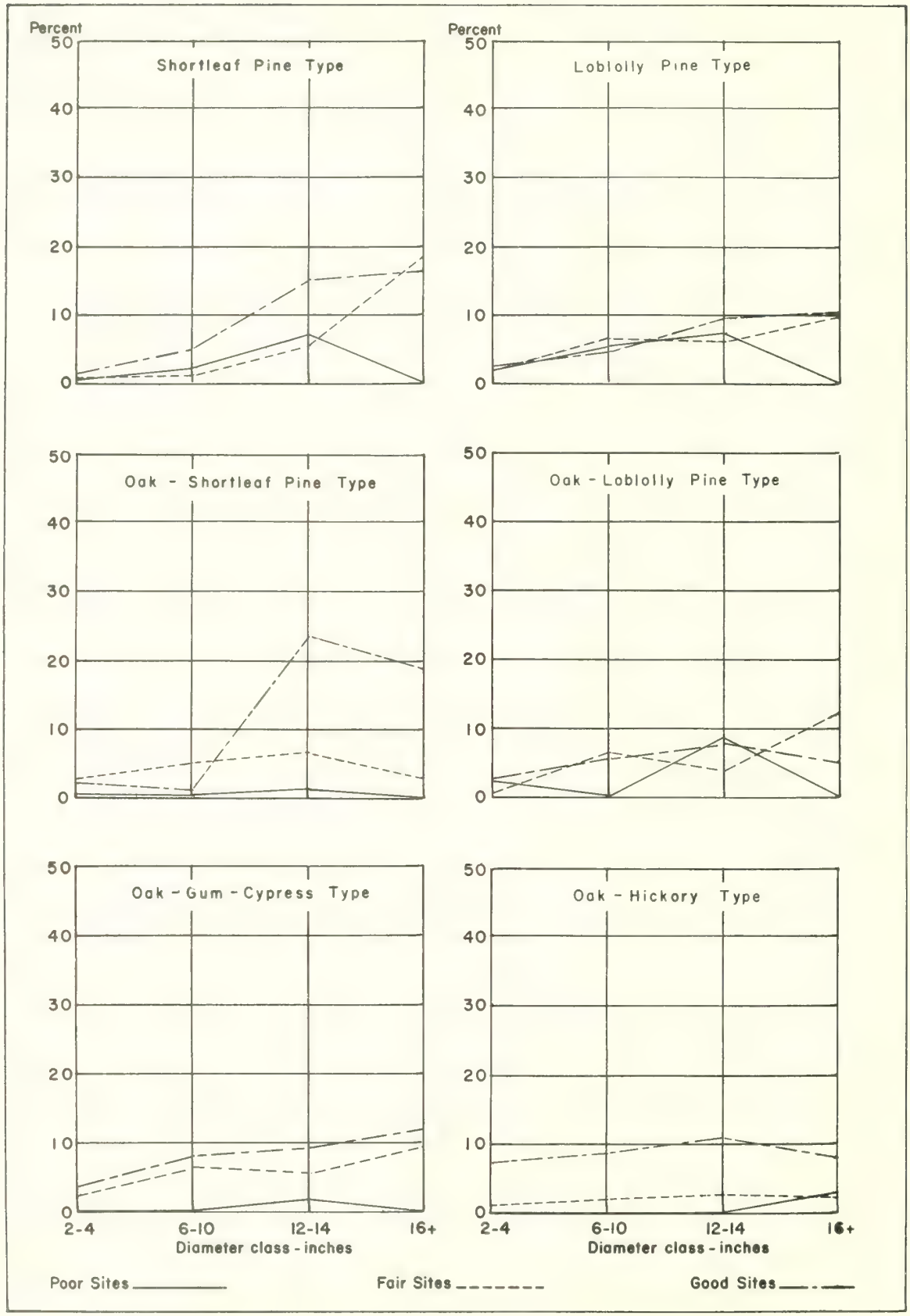


Figure 23.--Percent of the number of trees that are yellow-poplar, by forest type, site quality, and size of timber.

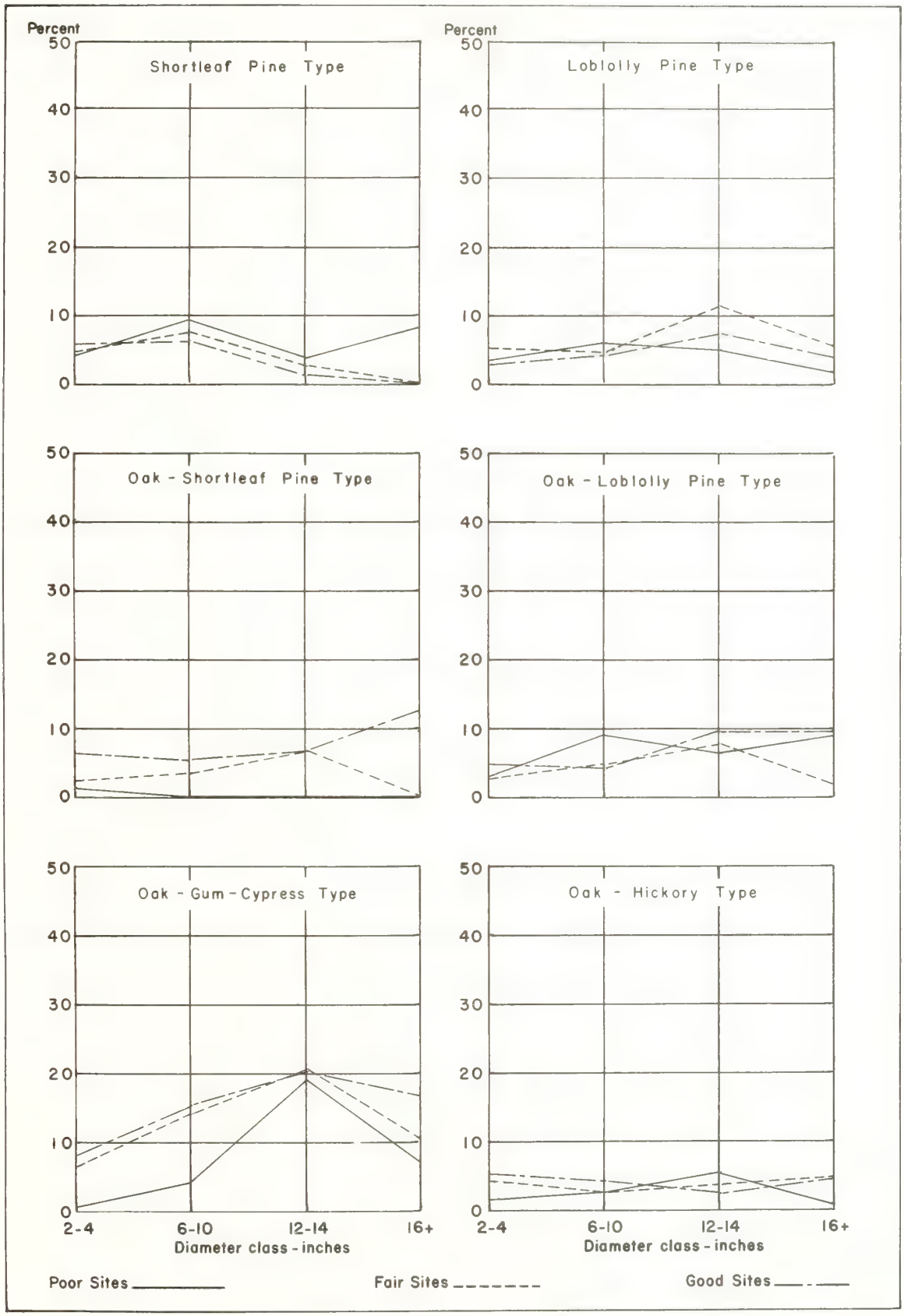


Figure 24.--Percent of the number of trees that are blackgum, by forest type, site quality, and size of timber.

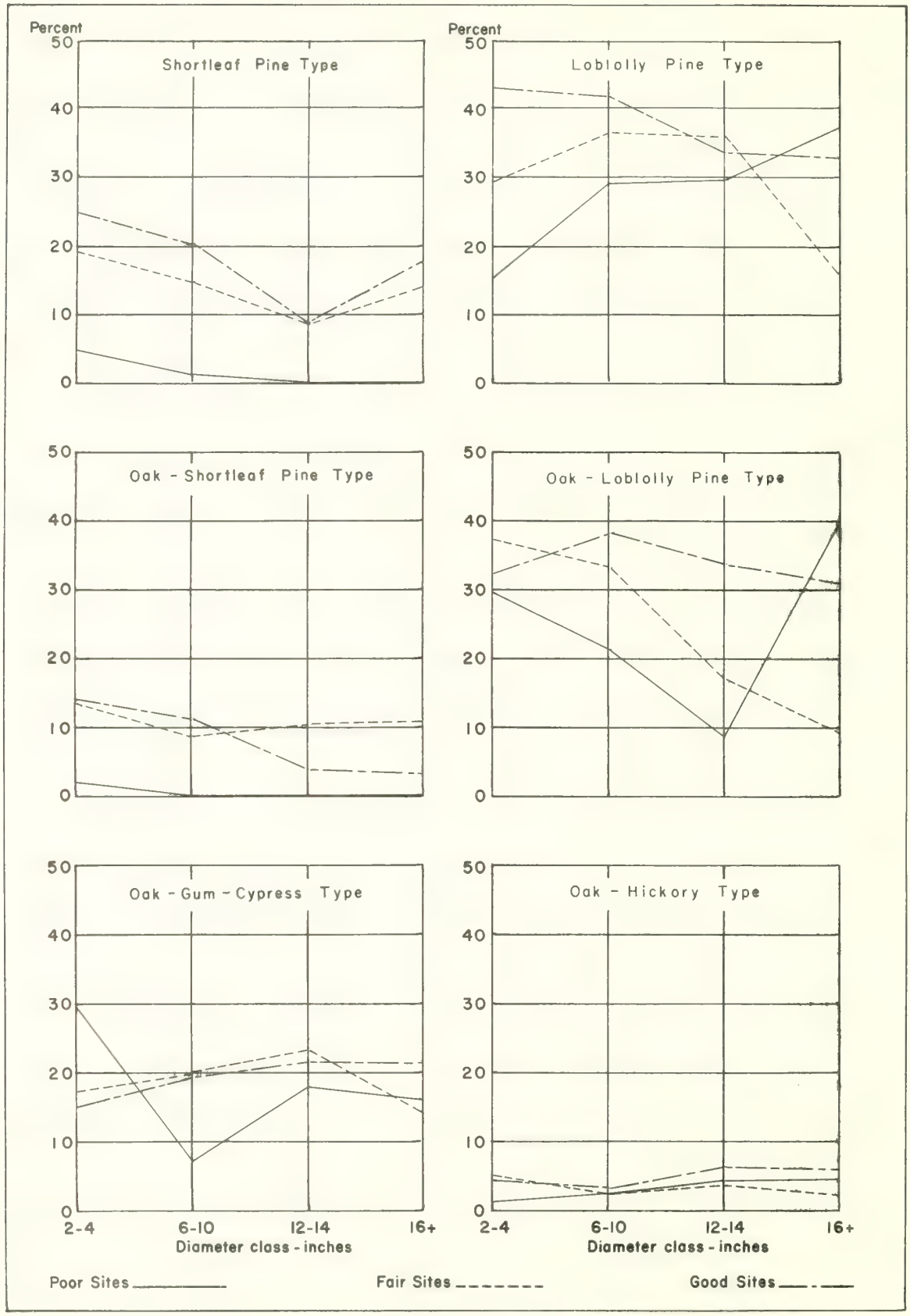


Figure 25.--Percent of the number of trees that are sweetgum, by forest type, site quality, and size of timber.

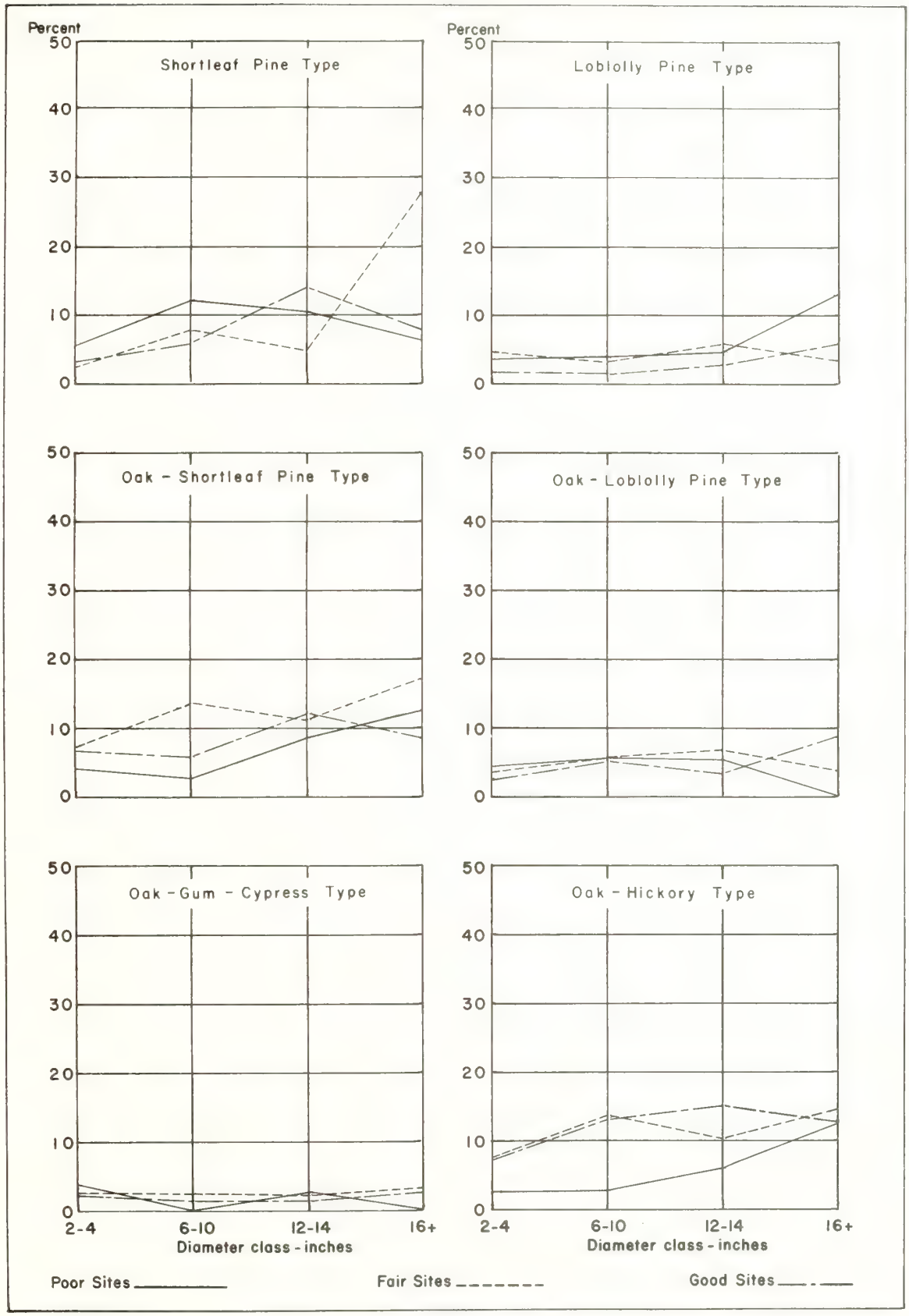


Figure 26.--Percent of the number of trees that are desirable white oaks, by forest type, site quality, and size of timber.

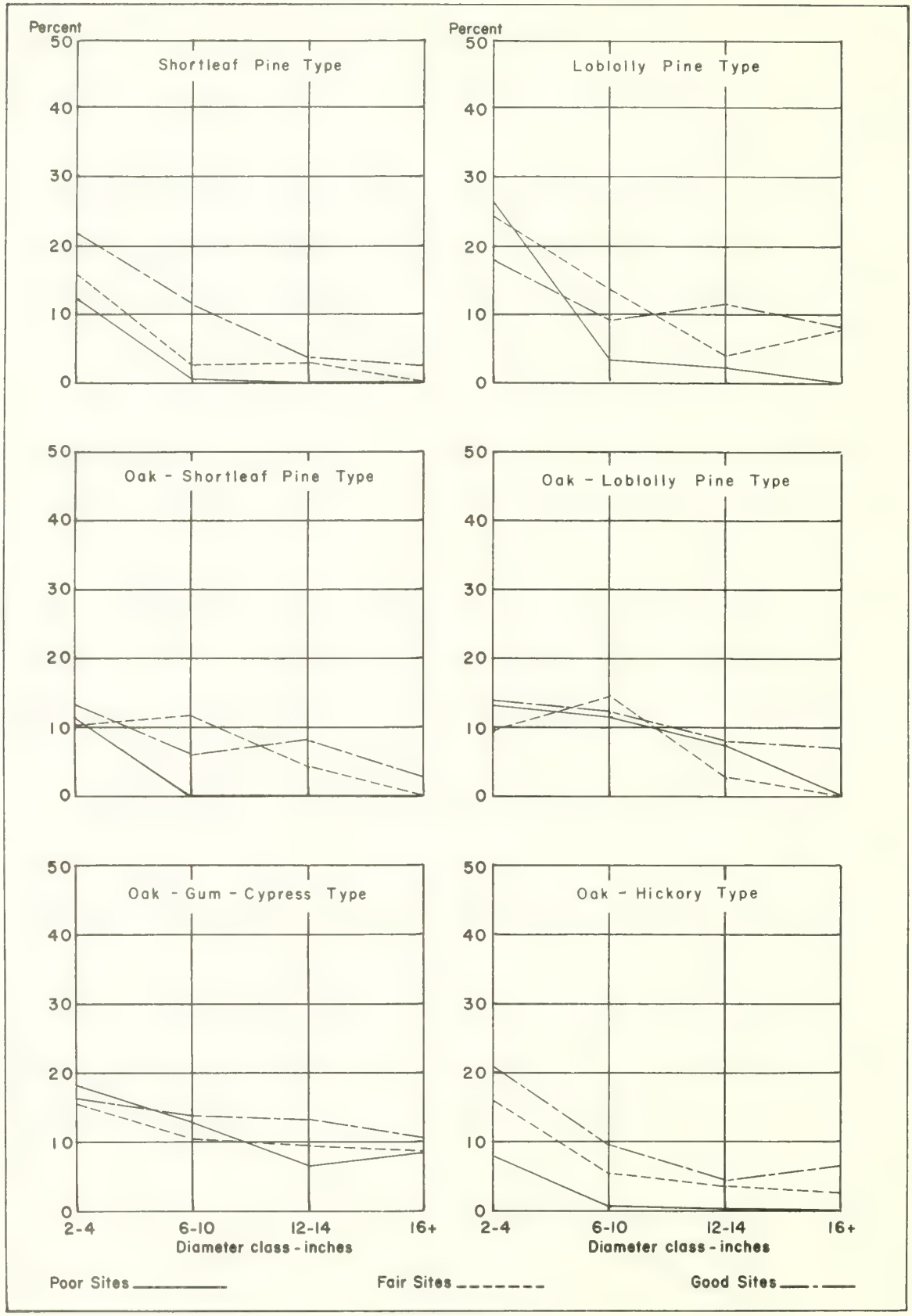


Figure 27.--Percent of the number of trees that are miscellaneous hard hardwoods, by forest type, site quality, and size of timber.

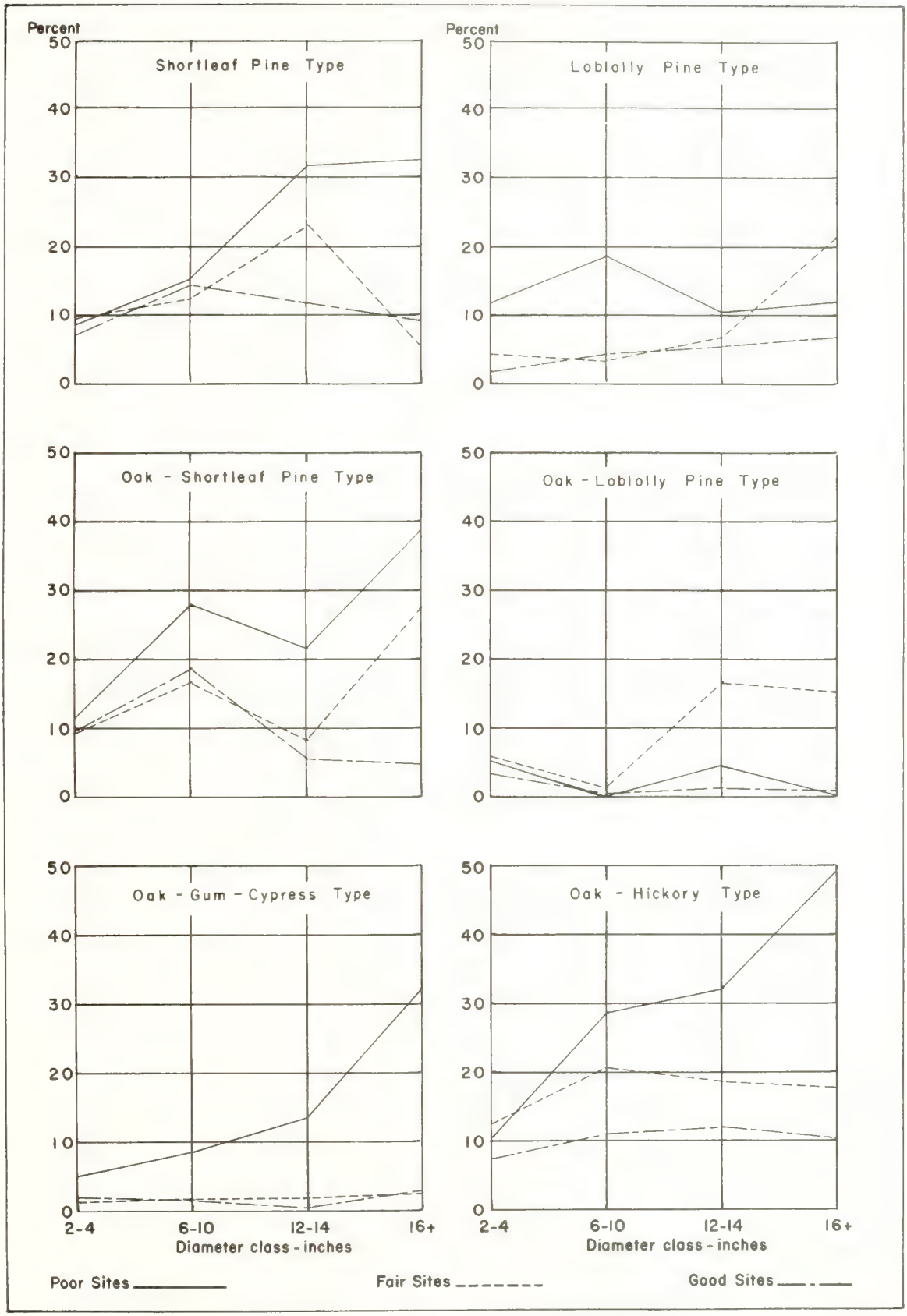


Figure 28.--Percent of the number of trees that are less desirable white oaks, by forest type, site quality, and size of timber.

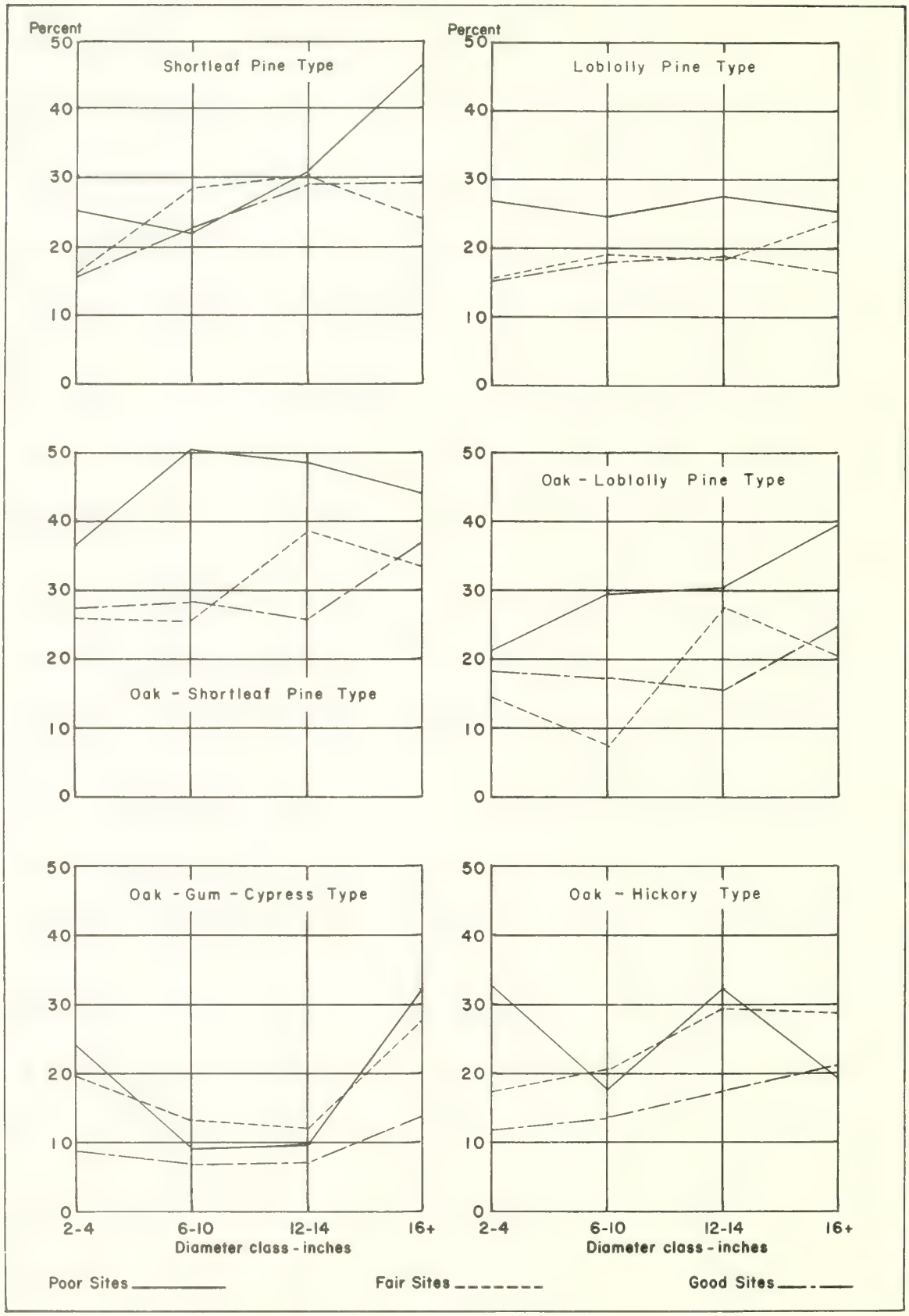


Figure 29.--Percent of the number of trees that are less desirable red oaks, by forest type, site quality, and size of timber.

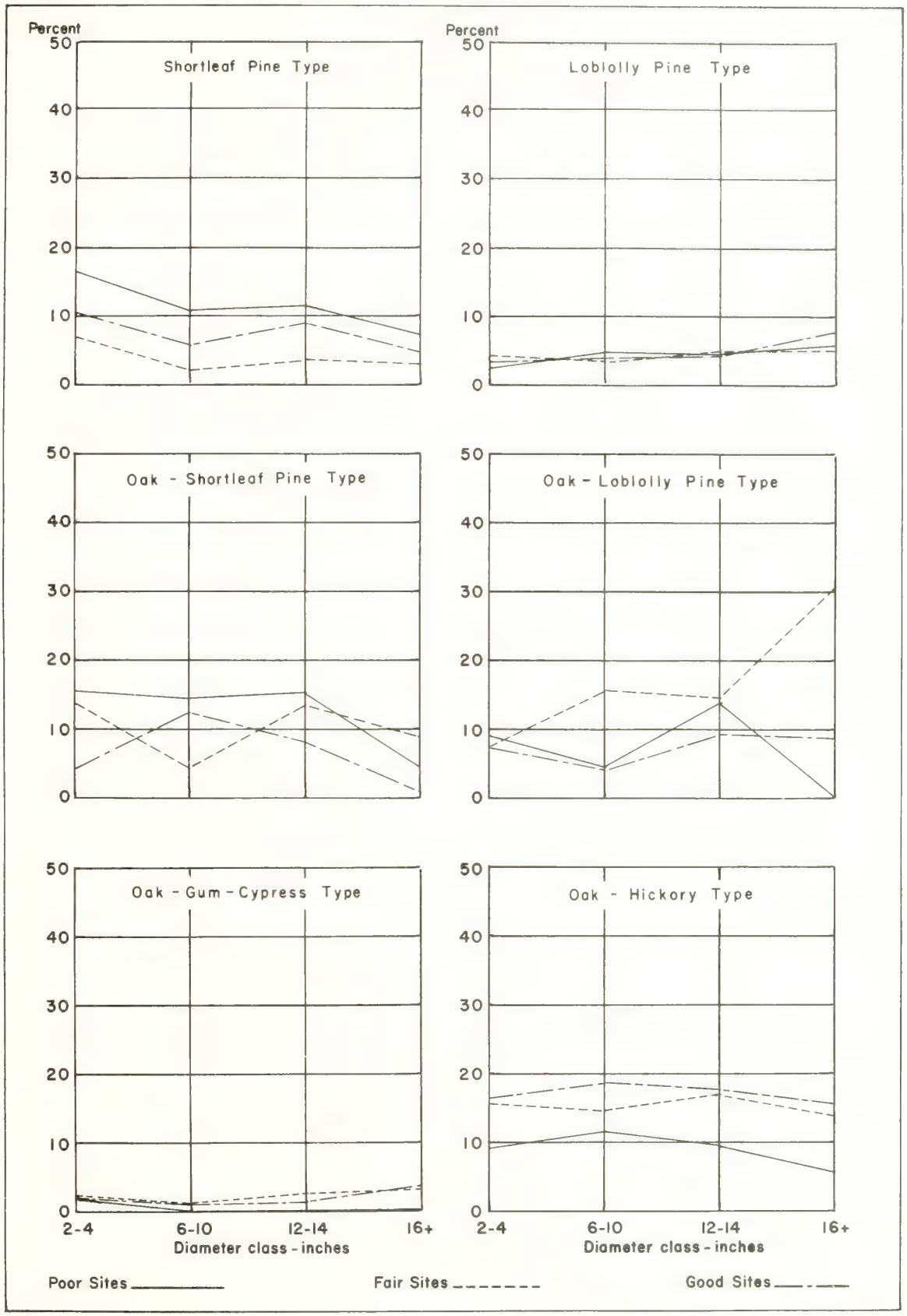


Figure 30.--Percent of the number of trees that are hickory, by forest type, site quality, and size of timber.

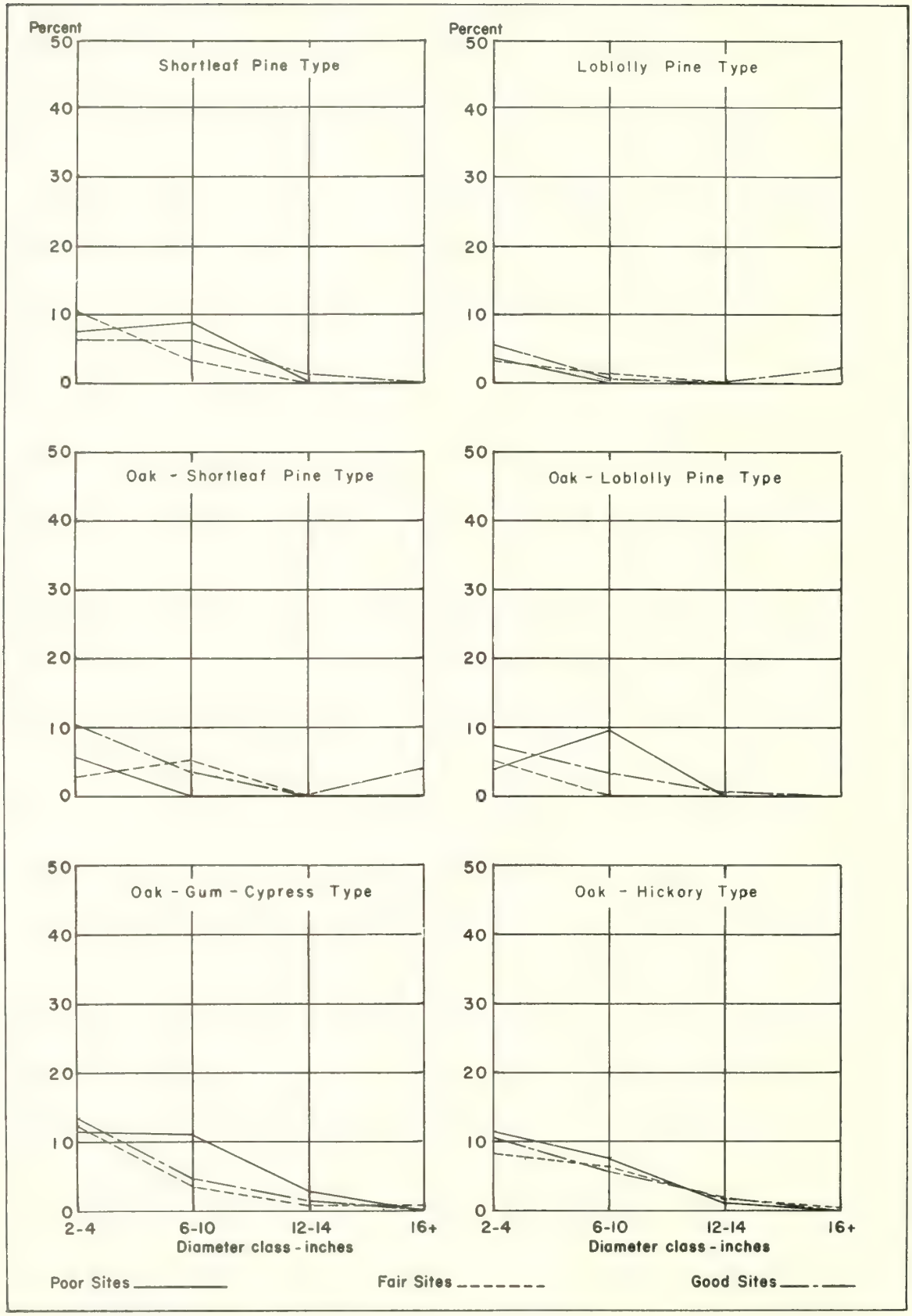


Figure 31.--Percent of the number of trees that are miscellaneous noncommercial species, by forest type, site quality, and size of timber.

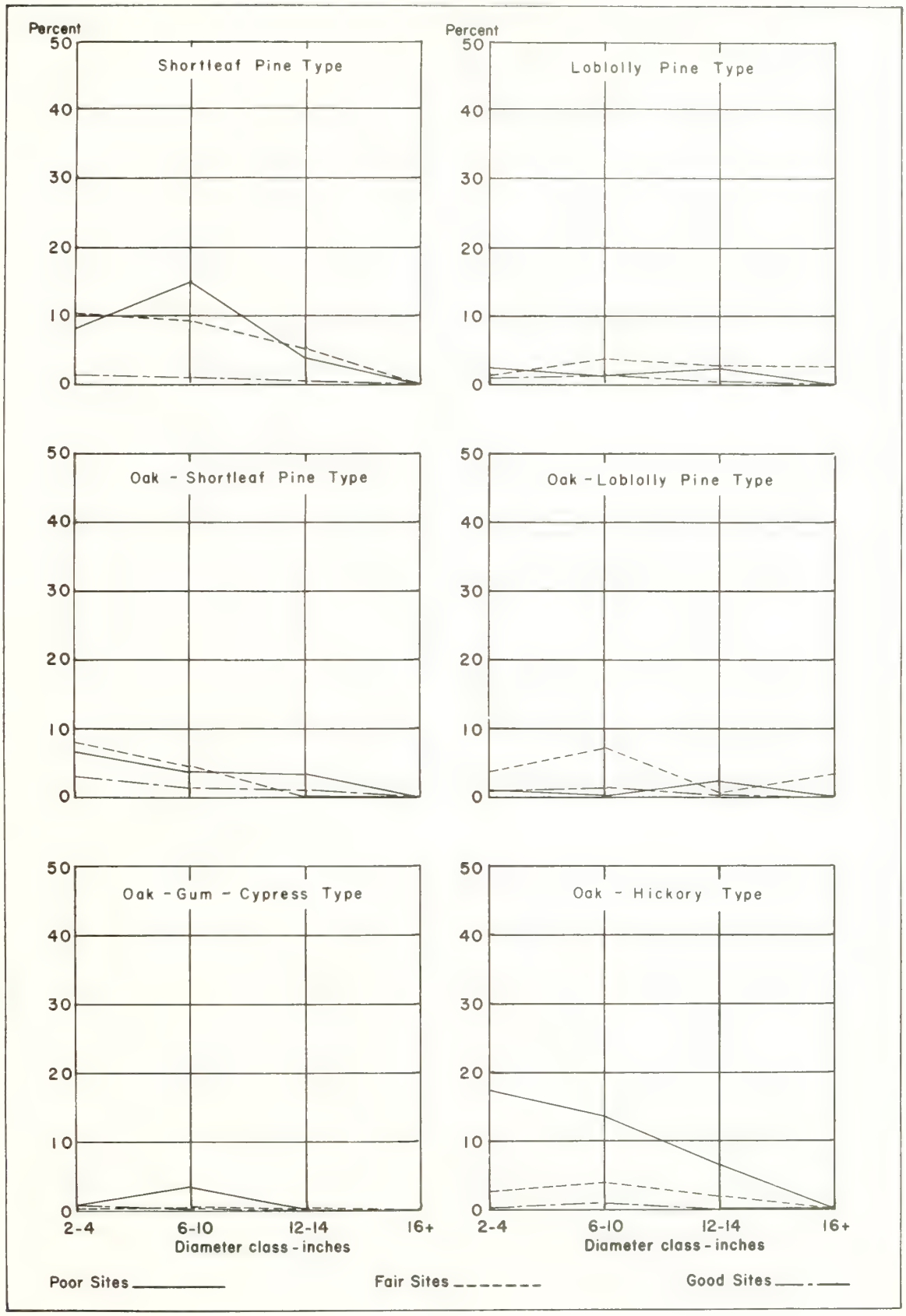


Figure 32.--Percent of the number of trees that are scrub oak, by forest type, site quality, and size of timber.

CONCLUSIONS

Landowners in central and north Georgia are faced with a rapidly increasing surplus of unmarketable hardwood timber and a decreasing supply of the pine and the large high-quality gum and yellow-poplar in great demand by forest industries. This abundance of low-quality hardwoods is not due to the inability of the forest land to support high-quality hardwoods, but to the long-standing practice of selecting the better trees for cutting and leaving the less desirable. At least 60 percent of the land in this area is capable of growing good quality hardwoods. Further study may show that additional areas will grow good quality hardwoods under proper management.

The ideal solution to the problem of surplus hardwoods is to find profitable use for them. However, at present the prospects of developing markets for any appreciable quantity of these hardwoods are not especially promising. Just to cut the growth of oak and hickory growing stock would mean cutting two and a half times the volume of oak and hickory now being cut. Practically all of this cut would have to come from trees 14 inches and smaller, as there is only a small excess of growth over cut in trees 15 inches and larger. Also, most of this cut would have to come from the least desirable species. Nearly half the oak and hickory volume consists of the less desirable oak such as chestnut oak, post, black, scarlet, southern red, and water oak. Fourteen percent is hickory.

In addition, there are the cull hardwoods, which for all practical purposes are not being used at all at the present time. Just to keep the volume of these cull hardwoods from increasing would mean cutting over a million cords annually--more than the volume of pine cut for pulpwood in this region in 1954. In addition to the annual growth, there is the present volume of nearly 30 million cords of cull hardwoods which should be removed from the stands to make room for better timber.

Use for fibre appears to offer the best prospects for utilizing enough of this surplus material to affect the trend. However, in 1954, only about 8,000 cords of hardwood timber were cut for pulpwood, and most of these were gum and yellow-poplar. Not all the cull timber is suitable for pulpwood; much of the volume is in large, rough, limby trees costly to log. It is estimated that not more than half the volume of cull timber is potentially suitable for pulpwood under existing logging methods. Counting half the growth on the culls and all the surplus growth on the poletimber, this region has about $1\frac{1}{2}$ million cords of hardwood timber available for pulpwood from current annual growth alone, or enough to supply several large pulp mills.

In the meantime, while landowners are waiting for markets to develop, they have the choice of girdling, poisoning, or in some way destroying these unwanted hardwoods or allowing them to take over more and more of the available growing space on their forest land.

DEFINITION OF TERMS

Land-Use Classes

Forest land: Includes (a) lands which are at least 10 percent stocked with trees of any size and capable of producing sawtimber or other wood products, and (b) lands from which the trees described in (a) have been removed to less than 10-percent stocking but which have not been developed for other use.

Forest Types

Forest type is determined on the basis of cubic volume for all stand sizes except seedlings and saplings (stand size 4), in which case the number of stems are the criteria.

Pine types: Forests in which 50 percent or more of the stand is in pine species. Plurality of volume or number of trees is used to determine the specific type.

Oak-pine type: Forests in which 50 percent or more of the stand is hardwood, usually upland oaks, but in which southern yellow pines make up 25-49 percent of the stand.

Oak-hickory type

Upland hardwood: Forests in which 50 percent or more of the stand is composed of upland oak, hickory, yellow-poplar, maple, gum, and other hardwoods, except where pines comprise 25-49 percent of the stand.

Scrub oak: Upland forests in which 50 percent or more of the stand is composed of scrub oak species, except where pines comprise 25-49 percent of the stand.

Oak-gum-cypress type

Lowland hardwood: Bottomland forests in which 50 percent or more of the stand is tupelo, blackgum, sweetgum, ash, oak, elm, maple, and associated species, except where pines comprise 25-49 percent of the stand.

Cypress: Bottomland forests in which 50 percent or more of the stand is cypress, except where pines comprise 25-49 percent of the stand.

Stand-Size Classes

Sawtimber: Stands containing at least 1,500 board-feet net volume per acre, $\frac{1}{4}$-inch log rule, in sound, live, softwood trees 9.0 inches d.b.h. or larger, or hardwood trees 11.0 inches d.b.h. or larger. Two classes of sawtimber stands are recognized:

Large sawtimber: Stands of sawtimber having more than 50 percent of the net board-foot volume in trees 15.0 inches d.b.h. or larger.

Small sawtimber: Stands of sawtimber having 50 percent or less of the net board-foot volume in trees 15.0 inches d.b.h. or larger.

Poletimber: Stands failing to meet the minimum sawtimber specifications, but at least 10-percent stocked with trees 5.0 inches d.b.h. or larger and with at least half the minimum stocking in pole-size trees.

Seedlings and saplings: Stands not qualifying as sawtimber or poletimber stands, but having at least a 10-percent stocking of trees of commercial species and with half the minimum stocking in seedlings and saplings.

Nonstocked and other areas: Forest areas not qualifying as sawtimber, poletimber, or seedling and sapling stands.

Diameters

D.b.h. (diameter at breast height): Stem diameter in inches, outside bark, measured at $4\frac{1}{2}$ feet above the ground.

Diameter class: All trees were tallied by 2-inch diameter classes, each class including diameters 1.0 inch below and 0.9 inch above the stated midpoint, e.g., trees 7.0 to and including 8.9 inches are included in the 8-inch class. Corresponding limits apply to other diameter classes.

Timber Quality Classification

Growing Stock

Sawtimber trees: Live softwood trees at least 9.0 inches d.b.h. and hardwood trees at least 11.0 inches d.b.h., with not less than one merchantable log 12 feet long, or with less than 50 percent of the gross volume of the tree in sound sawtimber.

Poletimber trees: Straight-boled trees between 5.0 inches d.b.h. and sawtimber size.

Sapling-size trees: Trees 1.0 inch to 4.9 inches d.b.h. which will grow into poletimber or sawtimber size trees of sound quality.

Other Material

Sound cull trees: Live trees of all sizes that are unmerchantable for saw logs now or prospectively because of species, poor form, excessive limbiness, or other sound defect.

Rotten cull trees: Live trees of all sizes that are unmerchantable for saw logs now or prospectively because of rotten defect.

Hardwood limbs: The limb volume of all hardwood sawtimber and cull trees to a minimum diameter of 4.0 inches inside bark.

Species Groups

Yellow pines: Includes longleaf, slash, loblolly, pond, and shortleaf pine.

Other softwoods: Pondcypress, baldcypress, and eastern redcedar.

Gum and yellow-poplar: Includes black and tupelo gum, yellow-poplar, sweetgum, and other soft hardwoods such as cottonwood, soft maple, basswood, magnolia, sweetbay, and willow.

Oak and hickory: Includes all of the oaks, hickories, and other hard hardwoods such as ash, beech, elm, river birch, hackberry, sycamore, black locust, mulberry, black walnut, holly, dogwood, and persimmon.

Volume Estimates

Board-foot volume: The volume in board-feet, measured by the International $\frac{1}{4}$-inch rule, exclusive of defect, of that portion of sound sawtimber trees between the stump and the upper limit of merchantability for saw logs.

Volume in cords: For sound trees the volume in standard cords (including bark) of the sound portion of trees 5.0 inches d.b.h. and larger, between stump and a minimum top-stem diameter of 4.0 inches inside bark. Similar volumes are given for cull trees. The volume in limbs, in sections 4 feet long and at least 4.0 inches in diameter inside bark, of all sawtimber-size hardwoods is shown separately.

Volume in cubic feet: Same as volume shown in cords except bark is not included.

International $\frac{1}{4}$-inch log rule: A rule for estimating the board-foot volume of 4-foot log sections, according to the formula $V = .905\ (0.22D^2 - 0.71D)$. The taper allowance for computing the volume in log lengths greater than 4 feet is 0.5 inch per 4-foot section. Allowance for saw kerf is $\frac{1}{4}$ inch.

Standard cord: A stacked pile, 4 x 4 x 8 feet, of round or split bolts, estimated to contain on the average about 73 cubic feet of solid wood.

Stocking

Stocking is the extent to which growing space is effectively utilized by trees of growing stock quality. The number of stems present by d.b.h. classes was used as a basis for stocking classification. Areas having the minimum numbers of trees listed on the following page, either in a single diameter class or proportionately in any combination of diameter classes, were considered fully stocked.

D.b.h.	Minimum number trees per acre
Seedlings	1,000
2 inches	800
4 inches	590
6 inches	400
8 inches	240
10 inches	155
12 inches	115
14 inches	90

Growth

Net growth: The estimated volume of net growth includes the growth on the present growing stock plus the ingrowth accrual resulting from smaller trees reaching volume size. It excludes mortality, or loss of volume in trees dying from natural causes. Net growth estimates are based on the volume or number of sound trees. Other material is not included.

In board feet: The change during the calendar year in sawtimber volume resulting from growth, ingrowth, and mortality losses.

In cubic feet or cords: The change during the calendar year in the volume of all sound trees 5.0 inches and larger resulting from growth, ingrowth, and mortality losses.

Timber Cut

The volume of timber cut is based on the measurement and tally of stumps found on regular ground sample plots. Stumps of all trees cut during the past 3-year period are recorded and the measurements are converted into equivalent tree volume. The average volume of timber cut for the 3-year period is then taken as the annual estimate. Board-foot cut volumes include the saw-log portion of all sawtimber size trees which were cut. Timber cut in cubic feet or cords includes the entire stem from stump to 4.0-inch top of all sound trees 5.0 inches in diameter and larger.

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Range Management Research in South Florida

A PROJECT ANALYSIS

by

Robert S. Rummell

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

FOREWORD

Management of the native range in south Florida has received little research attention until recently, although cattle have been grazed in Florida since the early 1500's. Many methods of livestock management have been developed, varying from excellent to poor. One very prominent Florida rancher has stated that Florida is now pioneering as the West was in the 1880's. Existing challenges if met can result in greatly increased productivity from the range.

The objective of the U. S. Forest Service's program of native range management research in south Florida is to meet these challenges. Through study of past land use practices, study of the literature and of research currently under way by other public agencies, major range management problems have been evaluated. A program based on relative importance, urgency, and susceptibility to solution through research has been proposed. The program and background evidence supporting it are presented in this project analysis.

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RANGE MANAGEMENT RESEARCH IN SOUTH FLORIDA

A PROJECT ANALYSIS

By

Robert S. Rummell

GENERAL DESCRIPTION OF THE PROJECT AREA

South Florida is a flat to gently rolling country of sandy soils, abundant ponds and marshes (fig. 1) with no point in the area more than 60 miles from salt water. The highest point is about 325 feet above sea level, and most of the interior is from 25 to 100 feet in elevation. Much of the extreme southern part is known as the Everglades, an area of low, grassy swamplands inhabited by abundant wild life, and is of little agricultural value unless properly drained.

The 17.6-million-acre area (fig. 2) supports extensive plantings of citrus, thousands of acres of winter vegetables, melons, and sugar cane, large phosphate diggings and fertilizer plants, commercial fishing fleets, pulpwood and lumber operations, and large herds of beef cattle which graze both native and improved ranges. All these are important to the area's economy.

In 1949, citrus, truck crops, livestock, and other miscellaneous agricultural crops including forest products sold from farms in the project area for 255 million dollars (64). Polk County alone mined about 70 percent of the world's supply of phosphate (22). Citrus grows on 394,000 acres (55) while about 277,000 acres of commercial vegetables, strawberries, and melons are raised (47).

Figure 1.--Broad expanses of flat terrain dotted with ponds and patches of pines and cypress typify south Florida. Scattered truck crop farms occur.

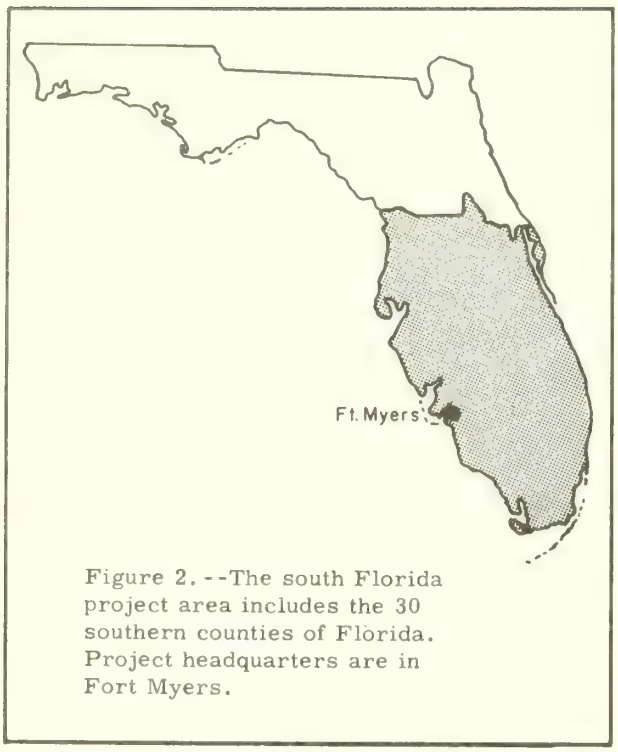

Figure 2.--The south Florida project area includes the 30 southern counties of Florida. Project headquarters are in Fort Myers.

Evidence of an expanding economy is seen in the 34-percent gain in population for the project area between April 1, 1950 and July 1, 1954. Population in the project area increased from 1,696,934 to an estimated 2,277,100 during this period, while State population increased from 2,771,305 to 3,493,100. 1/ Contributing to the welfare of the project area is a large percentage of the 5 to 6 million people who vacation in Florida and spend more than a billion dollars every year. 2/

Only 12.8 percent of the land in the project area is publicly owned; the remaining 87.2 percent is privately owned often in large tracts (appendix, table 3). For example, almost two million acres of land is owned by five of the largest companies or individual land holders. Other ownerships from 25,000 to 50,000 acres are common. The principal enterprise on the large land holdings is raising beef cattle, with interest in forest management showing up on individual ownerships. In 1950, the average farm contained 1,028 acres, compared to a state-wide average size of 290 acres (64).

CLIMATE

The climate is subtropical. Average monthly temperatures vary from 63.4°F. in January to 82.0°F. in August (fig. 3). Killing frosts may occur annually in the north half of the project area and are likely to occur in half the years along the coasts and in the area south of Lake Okeechobee (65). Humidities are high. Precipitation is highly seasonal and varies from an average of 2 inches in November to 7.47 inches in August. Annual precipitation averages 52.86 inches. During the low precipitation months beginning in late October and extending into May, many ponds and marshes go dry. However, with the onset of summer rains in June, these ponds and marshes fill up, and by late summer many low-lying tracts of land are flooded.

1/ Data from Bureau of Economics and Business Research, University of Florida; reported in Tampa Tribune, July 31, 1955.

2/ Cameron, Herbert D. Collins (Gov. Leroy) says state lure to industry not cheap labor. Tampa Tribune, July 30, 1955.

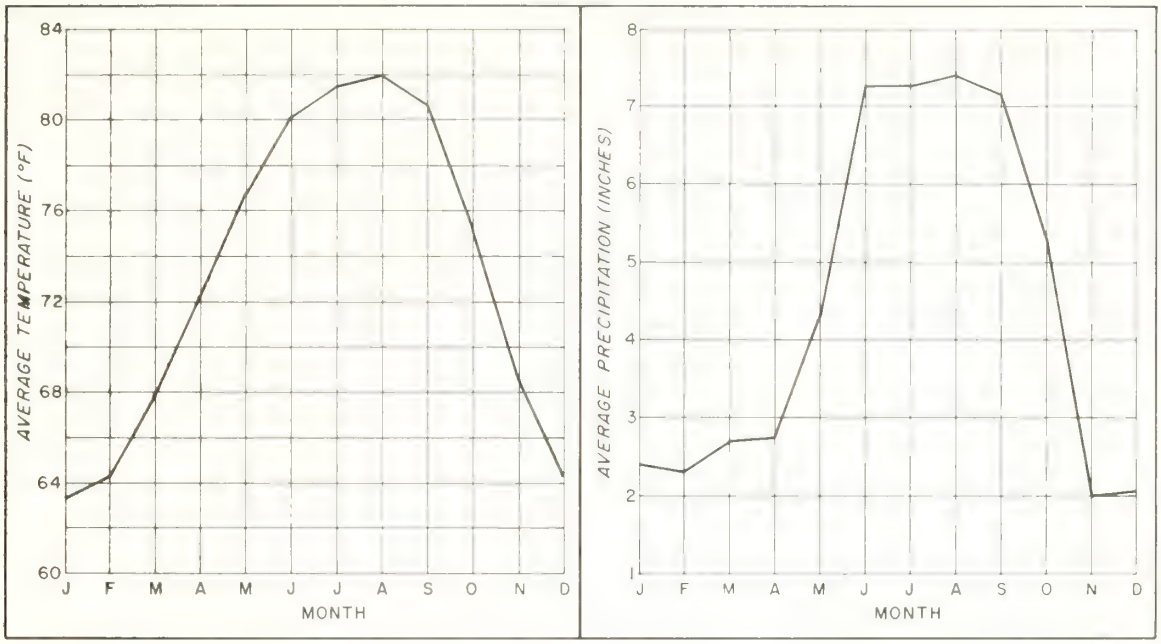

Figure 3.--Average monthly temperature and precipitation for 49 weather stations in south Florida project area.

SOILS

Most soils in the project area have developed from noncalcareous sands overlying limestone deposits (27). Eight of the Great Soil Groups are represented. These are:

(1, 2) Red and yellow soils (sands)
(3) Ground water podzols (sand)
(4) Half-bog soils
(5) Dry soils
(6) Bog soils
(7) Lithosols
(8) Alluvial soils

Generalized soil associations are presented in figure 4.

In general, the soils supporting range vegetation are sands low in organic matter, poorly drained (27, 39) and having a pH of 4.0 to 5.0 (32). Soils of organic origin exist in the Everglades region and are used for truck crops, sugar cane, and improved pasture when properly drained (27).

The soils generally are deficient in nitrogen, phosphorus, potassium, calcium and magnesium. In addition, certain soils also are deficient in copper, manganese, zinc and boron (27). Lime is frequently added to improved pasture soils to help correct soil acidity and as a source of calcium and magnesium (27). Magnesium deficiency is most pronounced in sands, especially in high, well-drained areas in the citrus belt, while copper deficiencies have been found on raw organic soils in the Everglades and some other areas (27).

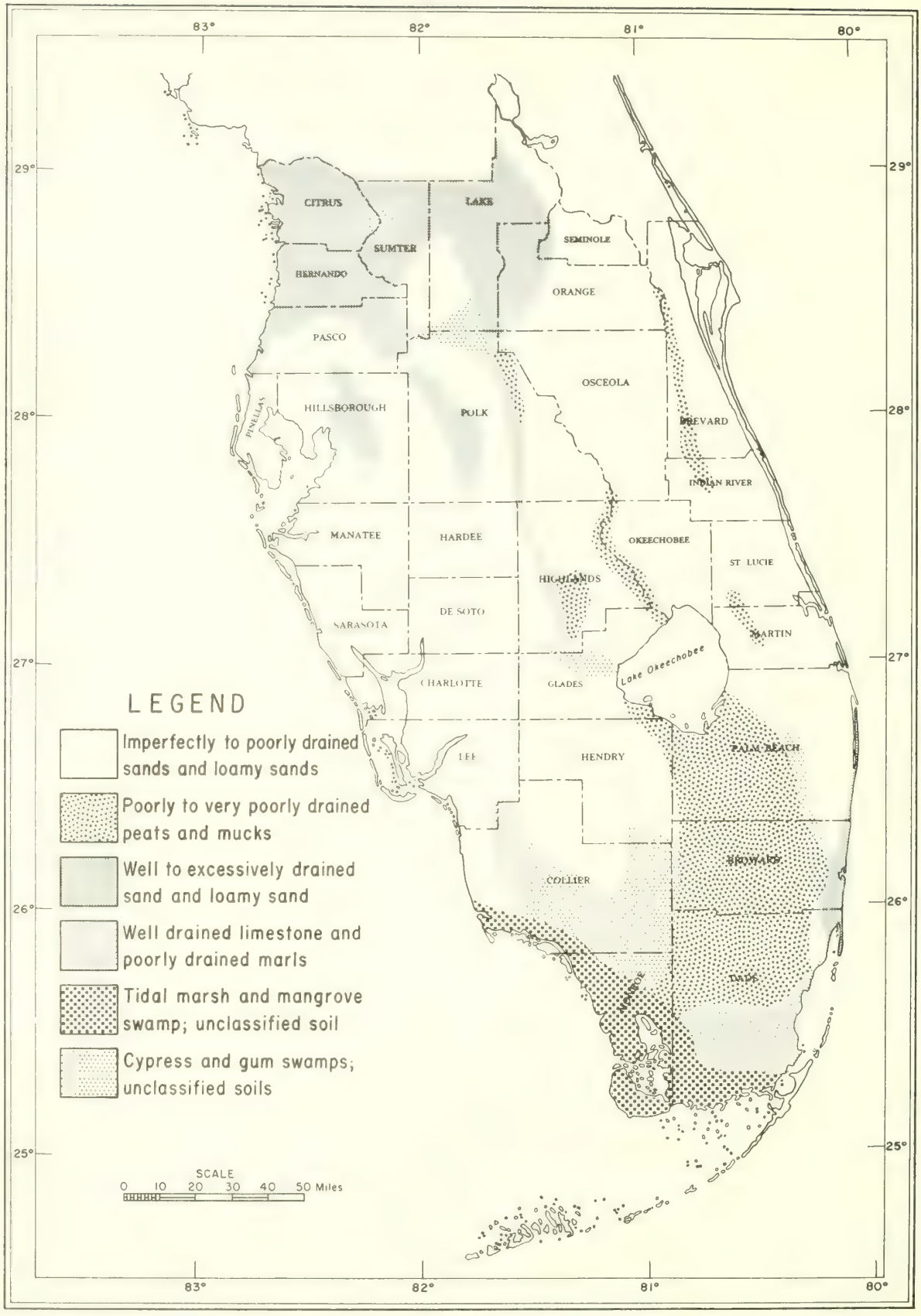

Figure 4.--Generalized soil associations in south Florida project area.

THE RANGE RESOURCE

Approximately 11.2 million acres or 65 percent of south Florida's lands are grazed or grazeable (appendix, table 4). Of this 11.2 million acres, 10.2 million acres are native rangeland. The remaining 1 million is land which has been improved by partial or total destruction of existing native vegetation followed by planting of a variety of pasture grasses (34). Locations of the major vegetation types are shown in figure 5.

Approximately 80 percent of the "land in farms" as defined by the 1950 census, is used for range and pasture (64). Lake, Dade and Monroe are the only counties with less than 50 percent of land in farms used for range and pasture.

Very little work has been done in classifying range vegetation into forage types, but work by Davis (15) provides excellent ecologic groupings, useful in delineating range types. For this project analysis, areas important for livestock grazing have been grouped into four plant associations, from material collected by Davis and information gathered by the U. S. Forest Service during 1954 and 1955. Vegetation on each of these associations is briefly discussed in the following sections.

Pine Flatwoods

Pine flatwoods cover about 5.7 million acres. They are spread over the north half of the project area from the Gulf of Mexico to the Atlantic Ocean, and extend down each coast line to the vicinity of Naples on the west and in a narrow band as far south as Homestead on the east. Five pines, South Florida slash pine (Pinus elliottii var. densa), longleaf pine (P. palustris), common slash pine (P. elliottii var. elliottii) and some loblolly pine (P. taeda) and sand pine (P. clausa) form the timber overstory which, though largely cutover, varies from sparse to fully stocked. Dominating the range aspect are saw-palmetto (Serenoa repens), grass species of the genera Aristida, Andropogon, Axonopus, Panicum, Paspalum, Sorghastrum, Sporobolus, other grasses and grasslike plants, a number of weeds and a variety of shrubs such as gallberry (Ilex glabra), staggerbush (Lyonia spp.), huckleberry (Vaccinium spp.), paw paw (Asimina spp.) and runner oak (Quercus spp.) (figure 6).

Over 170 species of forage plants were found by the Forest Service to be grazed during the summer of 1954 in the pine flatwoods type.

Dry Prairies

"Dry" prairies or naturally treeless ranges cover approximately two million acres in south Florida (fig. 7). They are quite similar in plant composition to much of the cutover pine flatwoods, except that they do not support pine trees. They do have scattered hammocks containing cabbage palmetto (Sabal palmetto).

Wet Prairies

Wet prairies generally are found in the pine flatwoods on very poorly-drained and frequently-flooded sites (fig. 8). They are readily distinguished from the dry prairie and pine flatwoods types by scarcity or absence of saw-palmetto (15). A great variety of forage plants occurs within this forage type. In 1954, the Forest Service found over 100 plant species which cattle had grazed in this type. Among the common plants are longleaf threeawn (Aristida affinis), panicgrasses (Panicum

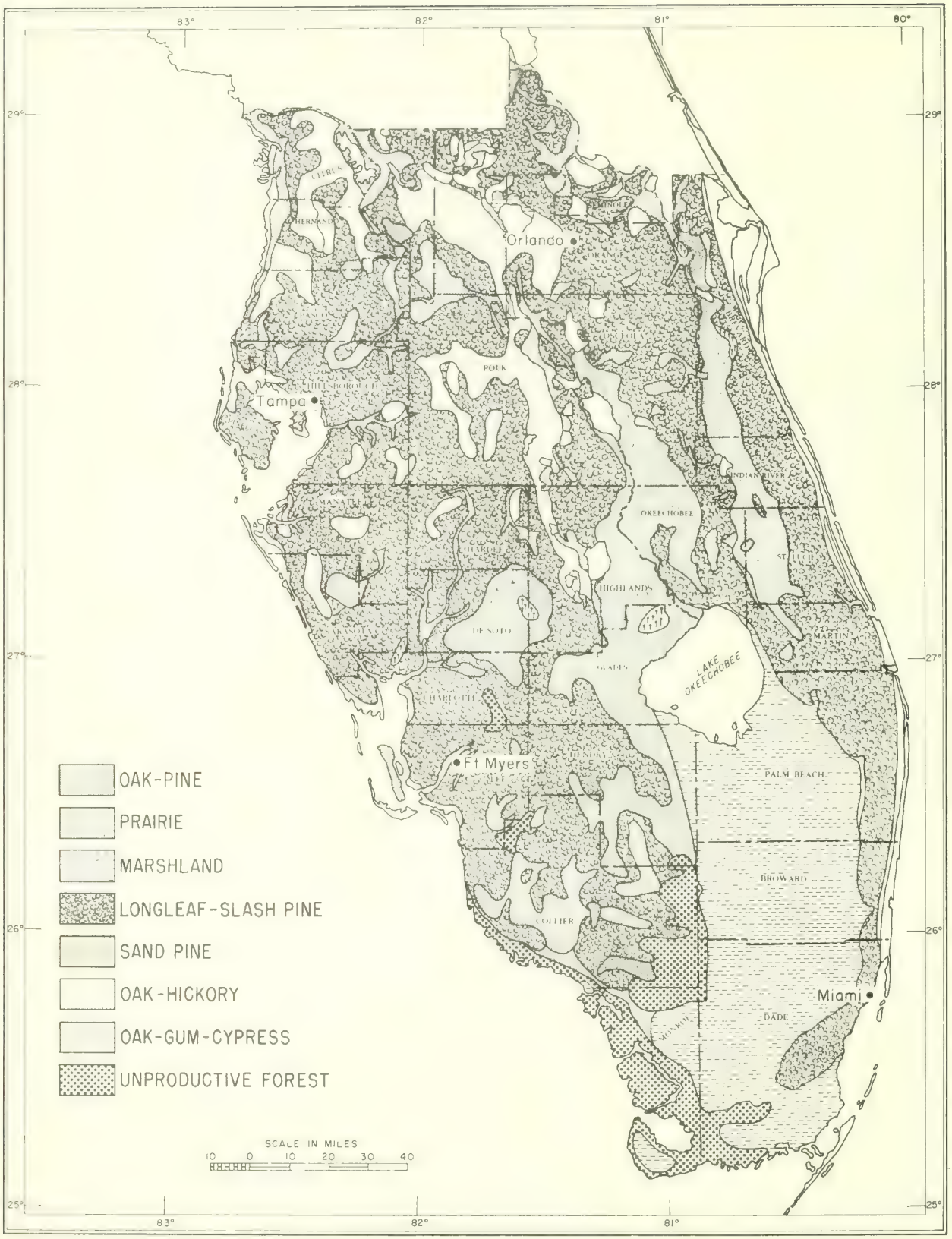

Figure 5.--Generalized major vegetation types in south Florida project area. Adapted from Larson (37).

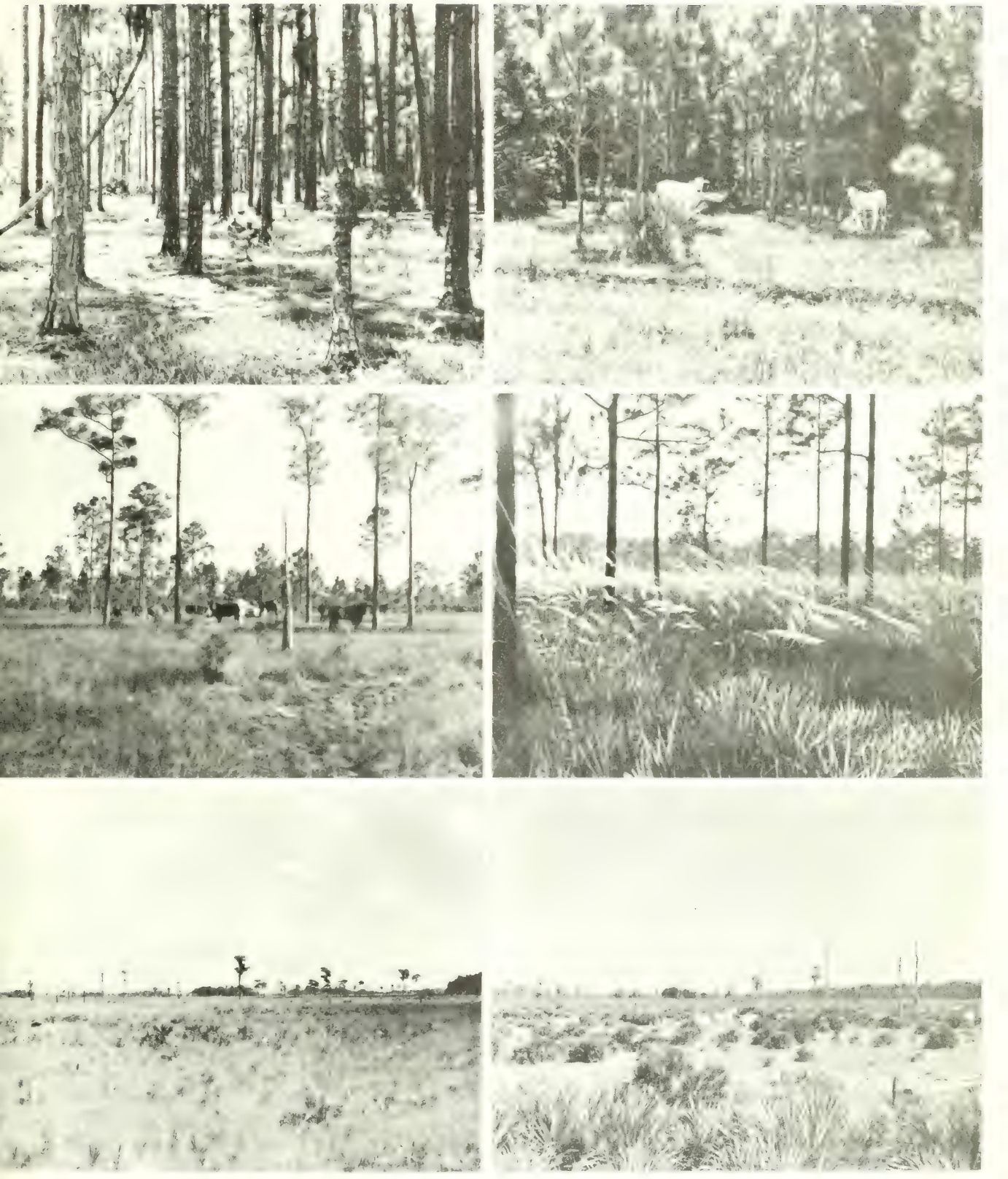

Figure 6.--Some pine flatwoods ranges are fully stocked with trees but most are cutover. Cattle obtain forage from forest ranges in all degrees of tree stocking.

Figure 7.--Treeless ranges or "dry prairies" are important forage producers in south Florida.

Figure 8.--Cattle frequently graze wet prairies in the winter and early spring.

spp.), lovegrasses (Eragrostis spp.), beakrushes (Rhynchospora spp.), nutrushes (Scleria spp.), umbrellagrasses (Fuirena spp.), St. Johnswort (Hypericum spp.), corkwood stillingia (Stillingia aquatica), marsh hay cordgrass (Spartina patens) and hairawn huhly (Muhlenbergia capillaris). Grazed plants such as maidencane (Panicum hemitomon) and bearded sprangletop (Leptochloa fascicularis) are found in many of the abundant ponds adjacent to the wet prairies.

Vegetative Types of Minor Importance

Although not of high forage value, hammocks and oak-scrub types are briefly discussed here because of their common occurrence in the project area.

In the oak-cabbage palm hammocks are found the cabbage palmetto, water oak (Quercus nigra), live oak (Q. virginiana), stiffcornel dogwood (Cornus foemina), baccharis (Baccharis spp.) and grasses and grasslikes such as Panicums and beakrushes. Principal value of these hammocks is for shade, protection from cold rains and wind, and for dry ground during seasonal periods of flooding.

Cypress hammocks are dominated by baldcypress (Taxodium ascendens), with several subdominants such as southern wax myrtle (Myrica cerifera), stiffcornel dogwood, red maple (Acer rubrum), pond apple (Annona glabra), and redbay (Persea borbonia).

The oakscrub association is a well drained white sand area represented by such dominants as myrtle oak (Quercus myrtifolia), sand live oak (Q. virginiana var. maritima), Asimina spp., and saw-palmetto. Some grasses and weeds occur but the type generally does not produce good forage.

FORESTRY

Approximately 53 percent of the project area is classed as forest land (44, 45), and most of this is used for cattle grazing. The land once supported good stands of pine timber but heavy logging since the 1920's, combined with a high incidence of wildfires and other fires set to burn off the "rough" for grazing, has left the forests in a severely depleted condition (fig. 9). In 1949, 86 percent of all commercial forest land and 94 percent of all commercial pine forest land was understocked with trees (fig. 10).

Value of forest products sold from farms in 1949 was only $627,000 (64). In 1954, pulpwood production amounted to 233,425 standard cords, which was only 14 percent of the production for the entire State (60).

Although timber growth potential on much of the forest land is not high (37), some of the large private land owners have profitable forest management programs under way. Preeminent among the factors preventing an acceleration of interest in forest management is the lack of organized fire protection project-wide. In 1954, only 9 of the 30 counties in the project area were wholly under forest fire protection by the Florida Board of Forestry (20). Sixteen counties had no fire protection. Another important deterrent to the practice of more forest management is the apathy among landowners, many of whom are engaged principally in raising beef cattle.

Figure 9.--Tree cover on much of south Florida's forest land is sparse and scattered because of heavy logging and frequent fire.

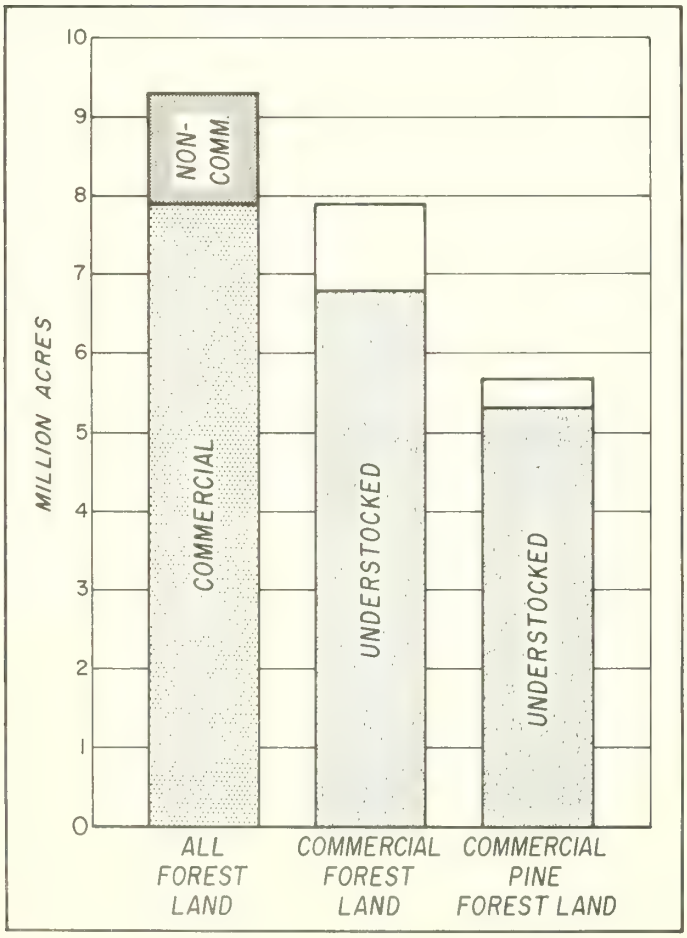

Figure 10.--Forest land and stocking condition in south Florida project area. Data from McCormack (44, 45).

Forestry and forest land grazing are not entirely compatible in the project area under present management systems. The periodic range fires annually destroy many young trees. If forestry is to assume importance as a major land practice, wildfires must be reduced in extent. Application of adapted controlled or prescribed burning techniques appears desirable on grazed lands where forestry is one of the important land use objectives.

With application of better fire control, natural regeneration of trees will occur where a seed source exists. However, since a high percentage of the forest land is understocked with trees, and natural regeneration would be slow to result in well stocked stands, forestry in the project area will be based principally upon plantations. How extensive will tree planting be? What will be the effects of tree plantations on the range picture?

From 1928 to and including the 1954-55 planting season, 38,000 acres of trees were planted in the project area (appendix, table 5). This is 8 percent of the 490,170 acres planted for the entire State of Florida in that same period. Recent accelerated interest in tree planting shows up in the 9,140 and 6,575 acres which were planted in the project area during the 1953-54 and 1954-55 planting seasons. This 15,715 acres amounts to 41 percent of the total acreage of trees planted since 1928.

Should planting be done at more than double the rate of the past two planting seasons or at 20,000 acres per year, 188 years would be required to completely reforest the 3,765,000 acres of poorly stocked and unstocked lands in the project area in need of planting (44, 45). To do the job in even 50 years would require nursery production of 51,204,000 seedlings per year. Additional seedlings would be needed to replant lands from which 25-year-old trees would be clearcut for pulpwood or on which trees might be destroyed by fire or other causes. It is difficult to see where this huge amount of seedlings would come from, especially when current nursery production available for the entire state is around 70 million seedlings and demand for them is expected to continue at high levels in those parts of the State not in the project area. In the 1954-55 planting season, 60 million seedlings were planted in the 37 Florida counties not in the south Florida project area, while only about 4.5 million seedlings were planted in the project area.

It is probable that tree planting within the next 10 years will result in a total of 125,000 acres of plantations. This would be a sizeable forest, but even so it represents only 1.2 percent of the total range area. The effect on range use could be of importance to specific property owners who engage in large scale tree planting but the over-all effect for the whole project area would be of minor significance.

Should reforestation by direct aerial reseeding prove practical in the future, or should a large pulpmill begin operation in south Florida, reforestation doubtless would be speeded up. The figures given above would not then apply and the impact on range use could be greater than presented.

SHIFTING AGRICULTURE

Truck crops are commonly raised in a shifting type of agriculture in south Florida (fig. 11). Range lands are cleared of natural vegetation, cultivated, and planted with vegetable or other seed. After one or two years' use, the land is abandoned because of excessive competition from Bermuda grass (Cynodon dactylon)

or disease problems. The farm operator moves to another piece of range or forest land and begins his cultivation anew. Size varies considerably, but "farms" containing from 60 to 320 acres are common.

Figure 11.--In south Florida's shifting agriculture, farms are carved out of forest and rangelands, one or two crops are raised, and the land is abandoned to grow up in miscellaneous grasses and weedy vegetation. The white line in the photo is a long mound of sandy soil left when a ditch was dug around this farm for 2-way water control--irrigation in the dry season and drainage in the wet.

Carpetgrass (Axonopus spp.) and Bermudagrass, which invade the cultivated areas, provide fair forage. Many ranchers allow cattle free choice between native range and the abandoned truck farm areas. While some operators do not encourage the productivity of grass on these areas, other operators try to convert them to improved pastures by planting Pangola (Digitaria decumbens) or other pasture grasses.

Accurate data on acreage are not available, but it is estimated that 100,000 acres are farmed by shifting agriculture each year in the project area. In the Immokalee area alone, between 10,000 and 12,000 acres of wild land are cleared for truck crops annually while a corresponding acreage becomes idle each year. Figure 12 shows the principal truck crop areas. Lands farmed by shifting agriculture are generally west of Lake Okeechobee in the interior of the project area.

WILDLIFE

Quail, turkey and deer, the most important shootable game species in the project area, live principally on lands used for livestock raising.

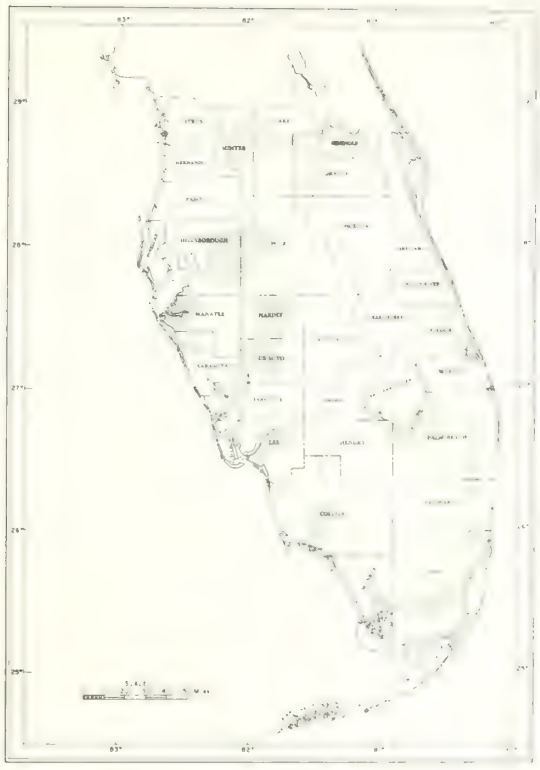

Figure 12.--Principal truck crop areas in south Florida. From Reuss (51).

Deer populations have increased during the past several years throughout Florida because of better law enforcement, public recognition of game regulations and improved habitat conditions. Upward trends in numbers are expected to continue for the next several years even though some loss in habitat will occur due to urban and agricultural expansion. Present deer populations are relatively low in the project area, with only 12,570 head reported (appendix, table 6).

The Florida Game and Fresh Water Fish Commission has found that controlled range burning combined with other management treatments is one of the most practical quail management techniques for south Florida cattle lands (9). Studies are under way by the Commission on amount of deer browse available under varying degrees of pressure from cattle and deer in various habitat types.3/

RANGE MANAGEMENT SYSTEMS AND PRACTICES

The native range continues to be the foundation of the Florida beef cattle business, and most beef cattle have access to native grazing land during some part of the year (32). A great variety of management systems and practices are used. Native ranges provide all the forage for many ranchers, some use native range in combination with improved pastures, and still others rely on improved pastures only. Discussions of these management systems follow, along with other important practices.

SEASONS OF USE

Many south Florida ranchers with fairly well drained land run cattle on the same range year-round without any system of deferment or rotation. Some ranchers rotate between ranges twice a year. Of necessity, other ranchers place cattle in the higher pine rangeland areas during the late summer period when extensive low-lying areas may be covered with 2 to 6 inches or more of water.

During the dry season cattle often make good use of forage growing in large sloughs or fresh water marshes (fig. 13). Frequently, the sloughs are a part of large pastures which contain higher forest rangeland. The entire pasture may be available to cattle yearlong but the marshes are less heavily grazed during high water periods. This, in effect, constitutes a type of grazing deferment system controlled by the amount of water present.

3/ Personal communication from E. B. Chamberlain, Jr., Chief, Game Division, Florida Game and Fresh Water Fish Commission (Aug. 19, 1955).

Figure 13.--Maiden cane and other valuable forage plants growing in ponds provide good forage in the winter and spring when they are accessible to cattle.

RANGE BURNING

Range burning, the most widespread tool of management used by ranchers on south Florida's native range, was carried out by Indians to stir up game and create habitats where game would concentrate. It was continued with the beginning of the turpentine industry to protect trees from accidental outbreaks of fire (6). Cattle ranchers now burn to destroy accumulations of dry grass and provide accessible green foliage for grazing during the winter and early spring (fig. 14). The green shoots of "wiregrass" (Aristida spp.) are reported to be about equal in nutritive value to most other grasses (17). Studies in other parts of the South have described the effects of burning on range plants, their nutritive values and cattle use patterns (7, 8, 25, 40, 56, 66).

Procedures used in burning vary considerably in accordance with the needs, habits, and desires of individual ranchers. Most burning is done from November through February, but some ranchers begin burning the range in September and some may burn as late as the first part of May. Some rangelands may be burned over every year, but the more common practice is to burn a unit of range every two to three years. One deterrent to yearly burning is the fact that not enough dead organic material accumulates in one year to carry a fire.

Some ranchers practice a scheme of progressive burning. They may set their first fires in November; about the first of January they set another series of fires to burn additional grass; still later, perhaps in the middle of February, they set another and last series of fires for the season. This progressive type of burning lengthens the period during which the native range grasses are palatable for winter and spring grazing.

Figure 14. --Uncontrolled grazing following severe winter burn has resulted in excessively heavy forage utilization on this south Florida rangeland.

Under the commonly employed methods of burning, tree reproduction and older trees frequently are injured or killed. Many ranchers who utilize native range for most of their forage say they could not stay in business without the use of fire. One large ranch burned 20,000 acres in 1953. A few ranchers mow rather than burn. Those who are forestry and conservation conscious deplore what sometimes seems to them a harmful practice.

The practice of range burning results in a kind of range deferred-rotation system. Cattle congregate on newly burned range during the winter and apparently obtain little forage from those parts of the range which are unburned. Since burning is done usually only every 2 to 3 years on one piece of native range, the unburned range could be considered to be deferred.

COMPLEMENTARY USE OF NATIVE RANGE AND IMPROVED PASTURES

Improved pasture plantings of appreciable size were first made in the mid-1920's, when common bahia (Paspalum notatum) and carpetgrass seed were imported (34). Argentine and Pensacola bahia (Paspalum notatum var. saurae), Bermudagrass, pangolagrass and St. Augustine (Stenotaphrum secundatum) now are among the more common improved pasture grasses (fig. 15).

Of the many ranchers who use both improved pasture and native range, some may have native range and improved pasture accessible at all times to animals; others rotate cattle between improved pasture and native range. Young brood cows are kept by some ranchers on improved pastures until they have had one or two calves. They are then run entirely on the native range for the rest of their productive life. One large ranch runs its cattle on improved pasture from October to February. Cattle are on native range from February to July. Pregnant cows are on improved pasture from July to October while the dry cows and steers are on native range.

Figure 15.--Mr. H. D. Ryals, De Soto County rancher, grazes steers on well-maintained pangolagrass pasture.

RANGE LIVESTOCK MANAGEMENT

Compared with other range areas, south Florida's livestock management practices generally are poor. Many improved livestock management methods are available but they have not been put into widespread use by ranchers grazing native range. Some current practices are discussed in the following sections.

BREEDS AND BREEDING

Since 1859, when four Brahman crossbred bulls were brought into the State by Daniel C. Ambler, [4/] significant progress has been made in upbreeding Florida's range cattle from the Spanish cattle introduced by Ponce de Leon in 1521 (21). Most of the native cattle now have been bred up with Brahman and British bulls (13). Approximately 70 percent of the commercial cattle in Florida have about one-half native and one-half Brahman breeding; about 20 percent have British blood, and approximately 10 percent have very little improved breeding. By 1950, Florida had over 550 purebred herds of beef cattle (34).

In Charlotte County, purebred Brahman bulls are commonly crossed with native cows for the first or second cross, then following with Angus, Shorthorns or Herefords. [5/] Brahmans, Santa Gertrudis, Aberdeen-Angus, Shorthorn, Charolaise, Charbray and Herefords are included among Lee County cattle. [6/] Brangus, Brafords, Beefmasters and Afrikanders also are used, while many cattle throughout south Florida display some evidence of Devon, Red Poll, and Ayrshire or other dairy type blood.

4/ Dodd, Dorothy. Popular Brahman cattle first introduced into Florida in 1859. Fort Myers (Fla.) News-Press, Feb. 17, 1954.

5/ McQueen, N. H. Better pasture grasses boost cattle industry. Fort Myers (Fla.) News-Press, February 17, 1954.

6/ Hueck, Carl P. Lee County farming one of leading revenue sources. Fort Myers (Fla.) News-Press, February 17, 1954.

Brahman-English crosses do well in south Florida's hot and humid climate. Furthermore, the introduction of some English blood has resulted in beef animals which better meet market requirements. The better blooded cattle purportedly require better ranges but improved blood of the desirable type will stand the range if managed properly (fig. 16) (42).

Although many good bulls are in service in Florida, an additional 18,000 good quality bulls are needed to replace lowgrade and scrub bulls (42). In 1948, 60 percent of a sample of ranchers having over 3,200 acres used purebred bulls exclusively (49). For a sample of ranchers having less than 3,200 acres, 84.4 percent used purebred bulls exclusively.

Even though many of the more progressive ranchers use a breeding season of 4 to 5 months, and separate bulls from cows at the end of that time, many other ranchers still leave bulls with the cows for a longer period--some even yearlong. This of course, means that calves are born throughout the year. According to a 1948 survey (49), the average length of breeding season on ranches of less than 3,200 acres was 8.6 months; on ranches of 3,200 acres and over, 6.7 months. Cows frequently are bred to calve beginning in December or January. Danger from screwworms and other parasites is low during this period and calves can be weaned prior to the high water season of late summer and fall.

Figure 16.--Excellent quality Brahman cattle frequently are grazed on forest rangelands.

Ranges containing 10,000 to 15,000 or more acres under one fence are not unusual. With this size acreage and with 500 to 1,000 or more brood cows in one range, effective service by bulls is difficult to obtain. Bulls commonly graze by themselves in groups of 3 to 5 or more and are not readily available when cows come into heat. Some ranchers attempt to obtain better service by placing bulls with cows in corrals, and then driving the herd back to the range after the bulls have had an opportunity to become associated with the cow group.

In Alachua County, number of cows used per bull varied considerably, although the average number was 32 cows per bull (appendix, table 7). A later survey showed somewhat similar results (49). On ranches with less than 3,200 acres, 36 cows were run per bull, with variation from 15 to 75 cows. For ranches having 3,200 acres and over, 29 cattlemen reported an average of 32 cows per bull, with variation from 15 to 50. Lewis (42) recommends one bull to 25 cows and never less than 3 bulls to 100 cows for Florida ranges. Cunha (12) says that many low calf crops in Florida may result from use of sterile bulls. He recommends one bull to every 15 to 20 cows on rough or poor ranges.

Parvin (49) reported for ranches 3,200 acres and over that the average age of heifers at first calving was 33.4 months. For ranches of less than 3,200 acres the average age of heifers at first calving was 30.0 months. Lewis (42) recommends that heifers be bred for the first time when they are about 2 years old, to calve at about 3 years.

CALF CROPS

Average calf crops in Florida are very low. For 1954, the average calf crop was reported as 50 percent, with a prediction that by 1964 it will have increased to 70 percent (18). Appendix table 8 presents some calf crops for 1935, 1940 and 1947 (49). Average calf crop percentage in Florida during 1953 was reported as 66 percent (29).

A major cause of low calf crops in Florida reportedly is underfeeding, usually associated with feed deficient in protein, phosphorus, and perhaps certain trace elements (29). In Alachua County the calf crop was found to be quite variable (6) (appendix, table 9). This was attributed to several factors of which the physical condition of the breeding animals was the most striking. Research in Georgia has indicated that quality of native forage was not high enough to satisfy requirements for lactation and reproduction at the same time (56).

Low calf crops are not, of course, universal. One large ranch which makes some use of native range but bases its management program principally on improved pastures reports a calf crop of 75 percent. Another large operator reports a calf crop of 65 to 70 percent. A third and excellent operator consistently obtains calf crops of 85 to 90 percent.

WEANING WEIGHTS

Weaning weights of range calves may vary from 225 to 400 pounds or more, depending upon age, breeding, time of calving, type of range, and management program. Some ranchers try to wean calves at 6 to 8 months of age, but calves frequently are left on the cow until 10 months or more of age. Some average weights of calves at 6 months of age are presented in table 10.

Calves born from December through February averaged 14 pounds heavier at weaning than those born in March and April in one study (50). One progressive rancher who practices excellent cattle management and who runs his cattle principally on improved pasture, but without supplemental feed, consistently weans calves in October at weights around 500 pounds.

HANDLING AND RAISING OF CATTLE

Throughout the south Florida range country, branding, dehorning, castration and inoculation are commonly done in the winter months, when danger from screwworm and other infection is lowest (fig. 17). Spraying for ox warbles and other parasites is done three or four times a year by the better operators.

Because of the year-round warm climate, barns or sheds are a rarity on south Florida's rangelands. During times of high winds or infrequent cold spells, cattle secure necessary protection in the forests or hammocks.

Cattlemen recently have shown interest in leaving patches of native pine or in planting trees for livestock shelter in their improved pastures. The Florida Board of Forestry has as one of the objectives of its Tropical Forestry Project the finding of exotic trees which could provide effective shelter.

Figure 17.--Calves are branded, dehorned, castrated, and inoculated during the late winter on the Collier Company ranch.

Mineral Supplementation

The need for proper mineral supplementation of range cattle has been recognized in Florida, although as late as 1931 only 15 percent of the range herds studied in Alachua County were supplied salt (6). By 1931, a nutritional anemia called "salt-sick" had been found to be the result of lack of iron or iron and copper in the forage (3). In some areas cobalt was found to be deficient. Other minerals that may be deficient in Florida range forage are calcium, phosphorus, and sodium chloride (2). Iodine is not lacking and no evidence has been found of nutritional deficiency resulting from insufficiency of fluorine, potassium, magnesium, manganese, sulfur or zinc (2).

A mineral mixture developed by the Florida Agricultural Experiment Stations has been recommended for range areas of Florida (2). It contains elements deficient in the forage, has good keeping qualities, and is palatable to cattle.

No mineral deficiency symptoms have been observed in Florida Agricultural Experiment Station herds while using the recommended mineral supplements, except for a few individual animals which do not eat the minerals (2). The factor most affecting mineral consumption has been the quality of the pasture as it reflects the soils and fertilization. The poorer the pasture, the larger is the amount of mineral supplement consumed. Cattle grazing recently burned native range or recently fertilized improved pastures reportedly eat little, if any, mineral supplement but an increase in mineral consumption has been noted as forage matures.

In studies by the Florida Agricultural Experiment Stations, cattle on unburned, unimproved pasture consumed an average of 77.64 pounds of mineral per head per year (2). This consumption was considerably higher than registered by cattle on range one-half of which was burned yearly and where cane molasses or fresh sugarcane or cottonseed pellets were fed. Consumption on the unimproved pasture also was higher than on pasture where the cattle had access to a combination of improved unimproved range.

A second wintering test with different animals showed lower average mineral consumption (2). However, average mineral consumption by cattle on unburned, unimproved pasture again was higher than consumption on pastures where different combinations of burning and supplemental feeding were used and where cattle had access to improved pasture and burned and unburned native range.

Analyses of "wiregrass" at the Range Cattle Station, Ona, Florida, showed an average calcium content of 0.54 percent and phosphorus of 0.08 percent (2). Calcium proved adequate for cattle obtaining all their feed from wiregrass grown on a fairly good soil but less than one-half the phosphorous requirement was met. Studies in Georgia (26) indicated that the native forage rarely meets calcium requirements and always falls below phosphorous requirements for normal growth of young animals and reproduction of lactating cows.

Water for Cattle

Throughout south Florida an adequate supply of water generally is available throughout much of the year. However, during late winter and early spring when many ponds and streams dry up, supplying adequate water can be a problem. Some ranchers pump water from shallow wells into troughs or let the water flow onto the ground. Other ranchers dig pits deeper than the expected low ground water level and allow cattle to obtain water there. Abandoned artesian wells left by itinerant truck farmers furnish water for cattle on other ranges.

Winter Feeding

During the winter, range cattle in Florida commonly undergo weight losses which may vary from 50 to 125 or 150 pounds (28, 29). These losses may affect the economy of the beef cattle operation through lowered calf crops and mortality of mature animals.

Loss of weight may result from lack of sufficient high quality feed on the range during the winter period (35). Grasses on sand lands in Florida start becoming low in protein as early as July, August, and September, depending on the area and type of soil (11). Seasonal variation in the amount and quality of forage on the range has been considered the most important factor responsible for weight changes of range cattle throughout the year (36). Other factors which cause loss in weight are extended periods of heavy rainfall when pastures become excessively wet, cold driving rains, and birth of calves.

Recent research by the Florida Agricultural Experiment Stations has shown the benefits of proper winter feeding. Cows fed oranges and grapefruit were in better condition than those on native pastures alone (35). While cows on native range alone lost an average of 51 pounds per head, those fed oranges lost 28 pounds. Cows getting grapefruit as a supplement lost only 10 pounds per head. Giving cattle free access to citrus molasses without adequate protein has not proved satisfactory under range conditions (35), and sufficient roughage and protein should be supplied along with molasses. Winter feed reportedly needs to supply from 7 to 9 percent total protein for range cows and 13 percent for weaning calves, or a high analysis (36 to 41 percent) protein supplement such as cottonseed meal is needed to raise protein content (29).

Hentges (29) states that Florida's major nutritional problems are a lack of adequate feed to properly winter gestating, lactating cows, and a lack of sufficient protein and phosphorus to nourish both the cow and the foetus.

ENEMIES OF BEEF CATTLE

Because of abundant moisture, favorable temperatures, and frequent concentrations of cattle, parasites have ample opportunity to increase in numbers. Among the external parasites which cause damage are horn flies, houseflies, stable flies, mosquitoes, horseflies, deer flies, screwworms, lice and ticks (61). Oxwarbles (Hypoderma lineata) appear in the backs of cattle in November, December and January and the flies of the oxwarble grub frequently bother cattle in late winter. Screwworms, which have been present since 1933, are particularly damaging to newly born calves and to animals at dehorning time or when the skin tissue is broken (63). Research currently under way by USDA may result in screwworm control throughout Florida through release of sterlized male screwworm flies. Plans are being laid for widespread control which may be undertaken by 1957 or 1958.[7]

7/ Unpublished statement by Dr. E. F. Knipling, Chief, Entomology Research Branch, Agricultural Research Service, USDA, to Florida Cattlemen's Association meeting, Fort Myers, Florida, June 17, 1955.

Liver fluke, lungworms, and stomach worms are important internal parasites. The yearly loss to livestock producers in Florida from liver fluke is estimated to be at least $100,000 (62). Liming to sweeten soil during truck crop farming or for improved pasture may foster liver fluke infections by providing good breeding conditions for the snail which acts as an intermediate host for liver flukes. Abandoned artesian wells also may provide good habitats for the liver fluke snail and result in greater cattle infestations.

Accurate information on livestock losses from disease is not available for Florida (57). However, anaplasmosis probably is one of the diseases causing frequent losses. Until eradication of the Texas fever tick through a concentrated dipping program which began in 1924 and continued in some parts of the project area until the early 1940's, Texas fever caused high losses among range cattle. Hyperkeratosis, or "X-disease," has been found in Florida's beef cattle herds (38). "Swollen joints," for which one of the causal agents is the microorganism Streptococcus pyogenes, has occurred on Florida ranges for a number of years and can be responsible for loss of 5 to 10 percent of the calf crop on individual ranches (16). Acute ergotism resulting from grazing Dallis grass, argentine bahia grass, and brownseed paspalum infested with the fungus Claviceps paspali (Stevens and Hall) has been observed in Florida (58).

West and Emmel (68) list a large number of plants potentially poisonous to livestock on Florida ranges. Losses from poisoning have been severe in some instances. In 1952, 25 head of cattle died on one ranch after eating seeds of coffeeweed (Glottidium vesicarium) (59). Losses from other poisonous plants are occasionally reported.

Loss from predators is negligible in south Florida. Although bear and cougar inhabit the Everglades and bobcats are fairly common, they do not cause significant losses. Occasional losses from snake bite and turkey buzzards do occur.

MARKETING

Florida's beef cattle industry is essentially a "cow and calf" business and is built around production of canner, cutter, and utility beef animals (46). A survey in 1953 (1) showed that 93 percent of the readers of the Florida Cattleman and Livestock Journal were in the "cow and calf" business and owned beef-type brood cows. Most cattle are marketed directly off grass, although interest in feeding is increasing rapidly (fig. 18). Evidence of the increase is shown in Fifield's (18) prediction that the number of steers on feed may increase from the estimated 1954 number of 25,000 head to 75,000 by 1964, followed more recently by Cunha's (14) statement that approximately 120,000 head of cattle will be fed out in 1956.

Although Florida currently produces only about 60 percent of its total beef and veal needs (55) cattlemen probably produce more low quality beef than is being consumed in the State (46). To meet the demand for top grades of meat, large volumes of good, choice and prime beef and beef animals produced in the midwest are shipped to plants serving Florida markets. A possible 75 percent of the steers fed out in Florida to good, choice and prime grades are produced in Georgia, Alabama, Tennessee and other states, and shipped into Florida as feeders because of the scarcity of high quality feeders produced in Florida (53).

Figure 18.--Feeding trials by the Collier Company proved successful in raising market grades of steers in 1955.

In 1953 only 10.1 percent of the slaughter cattle sold in seven Florida auction markets graded commercial, good, and choice (46). Less than 20 percent of the slaughter calves graded commercial, good, and choice and only 6 percent of the stockers and feeders sold in these auctions graded medium or above. Appendix table 11 presents data on number of animals by class and grade sold in five south Florida markets in 1954. The data in the table emphasize the low quality of Florida's cattle but they do not entirely show the true quality, for many of the better grades of animals are marketed by private treaty or direct sale. About one-half of the cattle sold in Florida are sold through auctions and about one-half are sold privately or direct to packers, dealers, or other farmers (55). Many of the auctioned cattle are desired by both stockers and slaughter buyers. As in other range areas, need exists for cattlemen to distribute marketings more evenly throughout the year to avoid market gluts in late summer and fall (55).

The comparative quality of Florida's cattle is reflected by the average value of $62.00 per head in 1954 compared to $92.40 for the entire United States (55). In 1953, the average live weight of cattle (excluding calves) slaughtered in Florida was 723 pounds compared to a national average of 937 pounds (48).

THE GRAZING SITUATION

LIVESTOCK NUMBERS AND GRAZING LOAD

Since the early 1500's, cattle have grazed the native range, and more recently, improved pastures, in generally increasing numbers. In 1924, the State supported 623,000 head of beef cattle (fig. 19). By January 1, 1954, the beef cattle population had reached an all time high of 1,386,000 head, ranking Florida thirteenth among all the States.

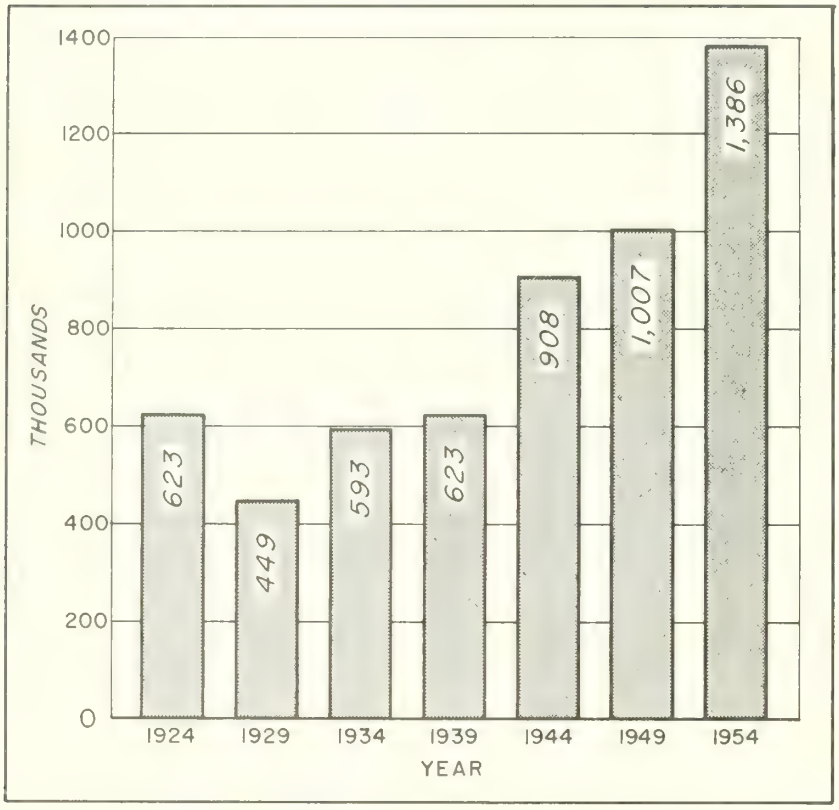

Figure 19.--Number of beef cattle and calves on Florida farms. Data from Scruggs and Scarborough (55).

Among the factors encouraging the increase in beef cattle numbers have been the eradication of the Texas fever tick and the great increase in acreage of improved pastures (42). Possible future eradication of the screwworm fly may favor further increases.

A million head of beef cattle graze the project area (fig. 20)--more beef cattle than are found in the individual western range states of Arizona, Idaho, Nevada, Utah, or Washington, and closely approaching Oregon, Wyoming, or New Mexico. Beef cattle numbers by class are shown in table 12.

The following tabulation presents data on size of cattle herds for Florida (1):

Cattle (Number)	Ranches (Percent)
More than 500 cattle	8
Less than 500 cattle	92
Less than 100 cattle	65

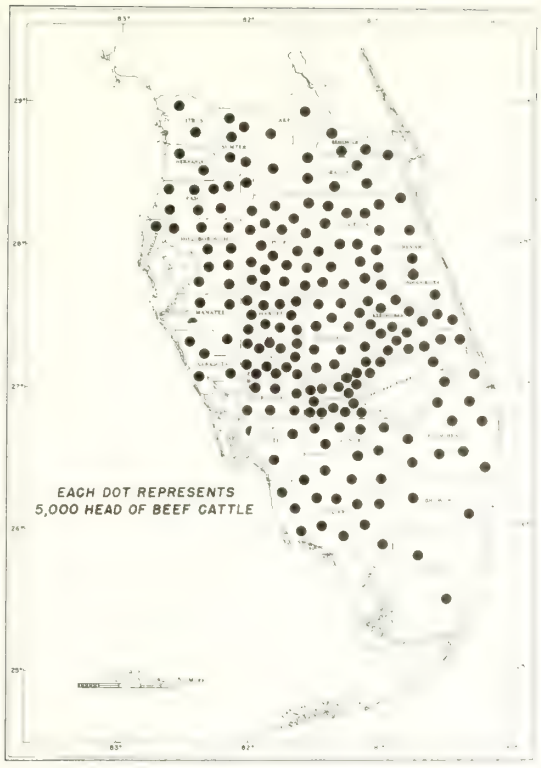

Figure 20.--The 1 million head of beef cattle in south Florida are distributed approximately as shown.

These data do not clearly represent the project area, for they include the many small ranches of northern Florida. For the project area, the percentage of ranches having more than 500 head would be higher than 8 percent. Many individual ranches have over 1,000 head of cattle and several support between 10,000 and 15,000 head.

In arriving at the grazing load in south Florida, it is necessary to convert grazing by the different classes of livestock to a common denominator. That denominator will be called an "animal unit." One cow, bull or steer over one year of age, or one mature horse or mule will constitute one animal unit. Mature sheep and hogs will constitute $\frac{1}{4}$-animal unit. All livestock less than one year old will be rated at 30 percent of mature stock for animal unit computations.

In following these computations through, it becomes necessary to determine the approximate ratio of total population of one class of livestock to mature animals of that class. For cattle this is done by the following: Total cattle population of the entire State of Florida January 1, 1954 was 1,679,000 (55). Of this, 255,000 were calves. The difference, or 1,424,000, is the cattle population over one year of age. The number of cattle units becomes 1,424,000 + (.3 x 255,000) = 1,500,500. The ratio of total cattle population to "mature" cattle becomes 1,679,000 to 1,500,500, or 1 to 0.894. Since 1954 or 1955 statistics are not available on numbers of calves for the project area, the statewide ratio determined from 1954 population will be used. This same ratio will be used for horses, mules, sheep and pigs. The figure 0.894 will be called an "age factor," and will be used to convert all animals to animal units. These computations leading to 1,060,030 adjusted animal units are presented in table 1.

GRAZING CAPACITY OF IMPROVED PASTURE AND NATIVE RANGE

An estimate of the grazing capacities of improved pastures and native range is difficult to obtain because of the wide variability in improved pasture development and management and the lack of well-founded data on native range production and grazing capacities. However, figures useful to this analysis have been secured by using published data on improved pasture grazing capacity and estimates of native range grazing capacity made in the literature and by reliable ranch operators and technicians.

Two acres of well managed and fertilized Pangola grass reportedly have carried a mature cow throughout the year and her calf to 6 months of age (32). If all of south Florida's estimated 1,000,000 acres of improved pastures were equally productive, the total grazing capacity would be around 500,000 animal units on a yearly basis. Using a more nearly representative figure of 3.5 acres of improved pasture per year, which is midway between the 3 to 4 acres Lewis (42) states are

needed, south Florida's improved pastures have a grazing capacity of 285,714 animal units. Since the project area has an estimated 1,060,030 animal units (table 1), improved pastures provide approximately 27 percent of the total amount of forage. The native range must provide the remaining 73 percent.

Table 1.--Estimated livestock units in south Florida project area as of January 1, 1955

Class	1950 1/ population	Percentage change 2/ 1950 to 1/1/55	Estimated population 1955	Animal unit factor	Gross animal unit factor	Age factor	Adjusted animal units	Percent of adjusted animal units
Cattle & calves	785,188	+46.4	1,149,515	1.00	1,149,515	0.894	1,027,666	96.9
Hogs & pigs	75,561	+15.6	87,348	0.25	21,837	0.894	19,522	1.8
Horses & colts	13,604	-19.2	11,128	1.00	11,128	0.894	9,948	0.9
Mules & colts	3,501	-17.0	2,906	1.00	2,906	0.894	2,598	0.2
Sheep & lambs	1,584	-16.4	1,324	0.25	331	0.894	296	T
Total	879,438		1,252,221				1,060,030	99.8

1/ U. S. Census of Agriculture, 1950 (64).

2/ Percentage change figures used are statewide. County figures unavailable. Statewide percentage figures provided by Florida State Marketing Bureau, June 17, 1955.

No records have been found of studies to determine grazing capacities of south Florida native ranges. The ranges have been stocked on an experience basis. In reporting on an experiment in which cattle were grazed on improved pasture with free access to native range at all times, Jones, Hodges, and Kirk (33) stated "it appeared that one acre of well maintained improved pasture replaced 8 to 10 acres of native range and provided higher quality feed over a much larger portion of the year, resulting in a larger calf crop and heavier and higher-grading calves at weaning." Although herbage yields were not measured in this study, it was estimated that the cattle obtained 30 to 40 percent of their forage from the native pasture.

Stockmen's estimates of grazing capacities in Alachua County are presented in appendix table 13. Other estimates on grazing capacity for native wiregrass range are quite variable. Blaser and Stokes (4) report from 5 to 20 acres are required to furnish grazing for one annual unit. For ranches having 3,200 acres and more, Parvin (49) reported an average grazing capacity of 14.8 acres per cow. For ranches having less than 3,200 acres, the average grazing capacity was 8.3 acres per cow. Hodges (31) says that native forage species growing on soils deficient in plant nutrients have a low grazing capacity with a cow unit requirement of 8 to 20 acres for year-round maintenance. Jones, Hodges, and Kirk (33) state that about 15 acres of native range is needed to support one cow weighing 800 to 900 pounds. Fifield (17) says tests have shown that 15 to 30 acres of native unimproved Florida range--mostly wiregrass and weeds--are required to support one cow on an annual basis.

For this analysis let us assume that the 10.2 million acres of native rangeland can be stocked at the rate of 1 cow for each 20 acres per year. Using this stocking rate, the grazing capacity of the native range becomes 510,000 animal units (table 2).

Table 2.--Estimated grazing capacity and load in south Florida for 1955 and 1964

Year and class	Area	Estimated grazing capacity		Estimated grazing load	
	Million acres	Acres per animal unit per year	Animal unit years	Animal unit years	Percent of capacity
The year 1955					
Native range	10.2	20.0	510,000	774,316	152
Improved pasture	1.0	3.5	285,714	285,714	100
Total	11.2		795,714	1,060,030	133
The year 1964					
Native range	9.2	20.0	460,000	666,286	145
Improved pasture	2.0	3.5	571,428	571,428	100
Total	11.2		1,031,428	1/ 1,237,714	120

1/ Assuming 20 percent increase over 1955 figures (18).

Since the estimated grazing capacity of improved pastures is 285,714 animal units and the estimated grazing capacity of native range is 510,000 animal units, the estimated total grazing capacity for the project area is 795,714 animal units. From table 1 it is seen that the estimated grazing load is 1,060,030 animal units. These calculations indicate that the native range and improved pastures are presently stocked at 133 percent of estimated grazing capacity. Fifield (18) has estimated that 90 percent of Florida's ranches are overstocked. The calculations in this analysis are not directly comparable to Fifield's estimate of overstocking, since they are based on animal units irrespective of individual ranch, but they do agree in general principle. Florida's improved pastures and native ranges are stocked at heavier rates than the current forage supply and levels of management warrant.

Further analysis of the data on stocking is desirable. The improved pastures have been shown to furnish 285,714 animal units if stocked at a rate of one animal unit to 3.5 acres per year. This requires the native range to furnish the remainder, or 774,316 animal units. Since the native range has been estimated to have a grazing capacity of only 510,000 animal units, native ranges are currently stocked at 152 percent of estimated grazing capacity.

Optimum animal production cannot be sustained from overstocked ranges. This has been shown by a large number of grazing trials (10, 54, 69). Continued overstocking eventually results in decreased animal production, followed by range retrogression. South Florida's ranges need relief from an overstocked condition.

By the end of the next decade, changes in major land use patterns will affect the range livestock rate of stocking and capacity situation. Fifield (18) estimates that improved pasture acreage will double for the entire State by 1964. For the project area, improved pasture acreage may increase to 2 million acres. Fifield (18) further predicts that numbers of cattle on Florida ranches will increase not more than 20 percent. Using these estimates of changes in major land use patterns and cattle numbers and disregarding possible changes experienced by populations of

livestock other than cattle (which currently total only 3 percent of the entire grazing load in terms of animal units), let us estimate the stocking situation and grazing load for 1964.

Improved pastures will increase to 2 million acres. Let us assume that the added 1 million acres of improved pasture will be obtained by cultivation and planting of lands currently now classed as native range. This may penalize the native range, since undoubtedly some of the increased improved pasture acreage will be obtained by reclamation or development of muck or marshlands and other lands such as abandoned truck crop acreage. However, for this analysis, we will reduce the present 10.2 million acreage figure for native range to 9.2 million acres.

If improved pastures and native range hold to their present estimated grazing capacities, the project area can support 1,031,428 animal units. The grazing load will increase to 1,237,714 animal units and we find that improved pastures and native ranges will be stocked at 120 percent of estimated grazing capacity. The native range will have to support 666,286 animal unit years while its grazing capacity will have been reduced to 460,000 by loss of 1 million acres to improved pastures. As a result, the native range would be stocked at 145 percent of its estimated capacity under present levels of productivity and management. The native range will be furnishing 54 percent of the forage, with 46 percent coming from improved pastures. Overstocking will still be a serious problem in 1964 unless present production levels can be raised on both improved pastures and native ranges.

Public agencies thus have a heavy obligation to provide range management systems which can increase productivity from the native range. Part of this obligation possibly can be satisfied by development of management systems which will result in increased grazing capacity. The remainder of the obligation must be satisfied by more efficient use of forage through improved means of livestock management.

Use of rangelands for tree growing will have some effect, though small, on grazing capacity. By 1964, an estimated 125,000 acres of native forest rangeland may be planted and managed principally for tree production. Range forage productivity in south Florida can be expected to decrease on tree-planted range areas somewhat in line with other parts of the South, where studies have shown that forage production is less beneath planted and other stands of trees than on open range (5, 23). Grazing demands on unplanted forest range lands will be somewhat intensified through this change in land use.

FEED SUPPLIES

The contributions made by improved pastures and native range far outweigh hay crops and silage, and concentrates. In 1949, only 5,406 acres were used for hay crops and silage, and production of hay amounted to only 11,363 tons (64). Within the past 5 years, alfalfa hay has been successfully raised on a limited acreage. Silage is coming into favor as a means of utilizing surplus summer forage and is being winter-fed, although in 1949 the project area produced only 869 tons of green weight corn silage (64). A marked increase in the use of silage for fattening cattle and for winter feeding is predicted by 1964 (18).

In the 1951-52 season, 200,468 tons of dried citrus pulp, 17,597 tons of citrus meal, and 54,183 tons of citrus molasses were produced in the entire state (55). These citrus products were second to corn as a source of concentrated feed

nutrients for Florida livestock. In 1952, 9,304,000 gallons or 55,824 tons of blackstrap molasses were produced in Florida (55). An estimated 15 percent of the citrus pulp and over 50 percent of the molasses produced in the 1949-50 season were fed to beef cattle (11).

The citrus byproduct feeds are rich in sugars and pectins but are low in protein, and are considered as energy feeds (35). Protein concentrates such as cottonseed meal or peanut meal are recommended for use with citrus byproducts in an adequate feeding ration (35).

DEFINITION OF THE PROBLEMS

This project analysis has weighed range problems according to their relative importance, urgency, and susceptibility to solution through research. Study priorities are based on these factors but also on available funds and personnel, and the extent to which other research agencies are studying the problems.

The many problems in south Florida rangeland use and management can logically be separated into six groups: (1) study of the range per se and determination of efficient ways to sample it (these are not range problems in the true meaning of the word, but they are tools through which the real problems can be solved); (2) problems revolving about major past, present, and possible future land management practices; (3) problems which have arisen from the kinds of range management employed; (4) problems associated with livestock management; (5) problems engendered by the inherent range enviroment; (6) problems in deer-cattle relationships on the range.

Study of the range per se and determination of efficient ways to sample it: In the south Florida project area there has been little study of the native range. The range management research program must begin by accumulating knowledge of what constitutes the range before progressing to studies leading to better management systems.

Highly important to the work is the cataloging of range plants. Over 350 forage species collected and identified in 1954 form a backbone inventory which will be important to technicians in all the future research (fig. 21). However, further intensive plant collection will be needed to assure that all range plants of significance are known and properly identified. The collection work should seek out grazed species, species which invade or regress with changing environment and which might be termed plant indicators, and species whose presence or absence may influence the micro-environment. Certain shrubs and broad-leaved trees will fall into this last group.

Studies of phenology and growth habits will be needed. Data on growth habits are essential for season of use and deferred rotation and other later studies.

Reactions of plant species to different grazing intensities, seasons of use, and other management treatments including fire will need to be measured through plant species composition, herbage production, and nutritive analysis studies. Changes in kind and amount of herbage produced can be one means for measuring the relative success of management treatments.

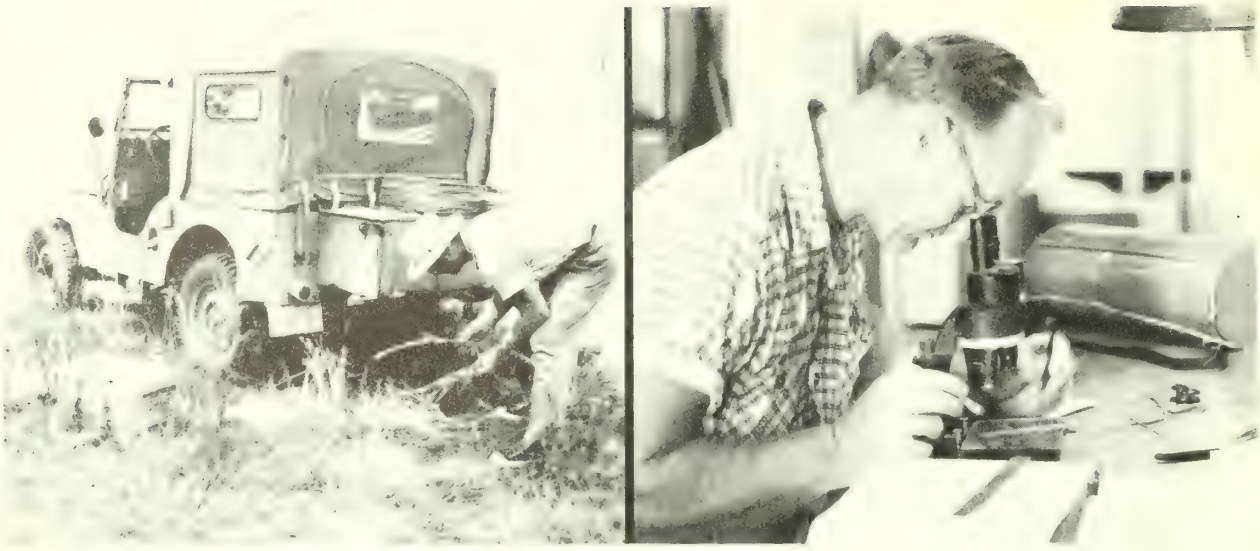

Figure 21.--Correct identification of range plants is an important part of range management research.

Plant species need to be grouped according to environment through ecological studies leading to more refined definitions of range types. Other studies should be designed to define range condition classes and prescribe ways for judging trend in condition. Such information will be valuable in establishing goals for the management of vegetation and will provide essential background information necessary in design of management studies. Studies in these fields are considered of high priority, for their results may influence correct interpretation of vegetation trends found in other studies. Findings should have immediate value to progressive ranchers.

Practical ways are needed for decreasing the abundance of saw-palmetto, a shrubby plant of low forage value (fig. 22). The Forest Service is constituted to study effects of different management systems on relative abundance of undesirable plant species, but studies in mechanical or herbicidal control will be encouraged from other properly constituted agencies. Studies in saw-palmetto control are relegated to medium priority in this analysis because the plant apparently resists control through management, because presently known herbicides or mechanical means for controlling it are costly, and because we need greater knowledge of its autecology before efficiently designed studies can begin. Incident to grazing capacity and other management studies, data can be obtained on the effects of the management systems on saw-palmetto.

Though existing devices and techniques for sampling vegetation will be useful under south Florida range conditions, studies in methodology are needed. The highly complex vegetation contains many species of little-known characteristics. Furthermore, the long growing season results in an almost year-round progression of plant development stages. Many forage species complete their growth cycles during the summer, while others continue growth into the fall and winter. Regrowth also occurs during the winter by some species following burning and quite possibly also following grazing of unburned herbage at that time. Forage plants entirely accessible during the dry season in ponds and sloughs are partially or wholly submerged in the wet season, and even submerged may form part of the cattle diet. Generally accepted experimental techniques for obtaining reliable data on herbage production, utilization, and even range condition and trend do not appear entirely suitable for south Florida.

Figure 22.--Saw-palmetto grows abundantly over much of the pine flatwoods in south Florida.

Problems revolving about major past, present, and possible future land management practices: For many of the 400 years during which Florida's rangelands have been grazed by cattle, fire has been used as a management tool. What has been the effect of fire on the range? Do we now have a disclimax vegetation type because of fire? If so, is this more desirable for grazing than the vegetation that might have occurred in relative absence of fire? What would that vegetation have been? If fire has not materially affected the species composition of the range since European settlement, then what have been the effects on amount of forage produced? What will the vegetation be if fire is kept out during periods of timber stand establishment? How has fire affected the soil? These are all questions which have not been fully answered, although studies in the South provide good leads (24, 25, 30, 41, 56). In the answers lie the means for more efficient use of rangelands.

Study of ecological aspects of burning is rated of high priority because the range is almost universally burned, because the hypothesis exists that burning as currently practiced is detrimental to range vegetation and other land resources, and because reports have been published supporting benefits from fire (25, 30, 67).

Once knowledge on ecological effects of burning has been obtained, studies leading to development of improved burning methods can be instituted. Studies leading toward improved systems of burning for range purposes must include study of effects on trees. Extention to the project area of prescribed burning methods developed through research in other parts of the South may be beneficial. However, because of the peculiar conditions of climate, soils and vegetation in this project area, local research is needed. Such studies are rated of medium priority.

Heavy cutting of south Florida's timber has brought questions needing answers. To what extent has the livestock operator benefited from complete removal of the timber overstory? Herbage production probably has increased, but there is no experimental evidence as to the amount of the increase. Nor is there recorded evidence of species composition changes which have occurred because of changed micro-environmental conditions.

What species composition changes can be expected in the next 50 to 100 years on cutover forest lands, both unplanted and planted? Will these changes be significant? Studies to find out the answers to these problems may be difficult, but the information will be important to landowners in deciding how far to go in reforestation. The results may significantly affect the extent to which future range management research will be needed.

For those lands where an intensive forest program is planned, studies are needed to find how forestry and range management can be integrated. The extent to which forestry will be practiced as a major land management objective in the project area must be analyzed in evaluating the need for such studies.

This analysis has shown that 86 percent of the commercial forest land is understocked with trees. Future forestry activities on approximately 3.75 million acres now devoid of seed trees must of necessity be based on planted stands. Appendix table 5 has shown that only about 38,000 acres of trees have been planted in the project area since 1928 and that this represents only 8 percent of the planting made during the same period for the entire State. Other analyses based on this table indicate that even with greatly accelerated rates of tree planting, encouraged by better fire protection project-wide, complete reforestation may not occur within the next 50 to 100 or more years. Limitations of production of tree seedlings would be one important factor. Another factor is the management goal of private landowners who own 87 percent of the land in the project area. Some large owners are growing wood products from plantations along with raising beef cattle, but most smaller landowners have not planted trees.

Because of the strong interest in cattle raising, the probable minor role of forestry within the next decade, the large backlog of unsolved problems in managing the range, and the lack of proven experimental range measurement techniques, emphasis should be placed first upon solving the range problems per se and then considering the problems involved in fitting tree growing and grazing together. Problems in integration, thus, are rated of high relative importance, but current medium priority.

Studies in integrated use should provide methods for securing most efficient grazing use of forest rangelands managed for pulpwood production. Studies also should be directed towards the effects of grazing--including soil compaction, physical disturbance of tops, and browsing--on both planted trees and natural regeneration.

Though old growth forest stands in the project area are not plentiful, studies on the integration of timber production and grazing should be designed to yield information applicable to such stands.

Studies in other parts of the South (5, 23, 25) and observation in the project area have shown that herbage production drops as the forest canopy closes. Within this project area plantings are being made of the South Florida slash pine (Pinus elliottii var. densa), a tree found only in the Florida peninsula and its keys (43) and which may have growth responses different from other pines planted elsewhere in the South. Studies are needed in planted tree stands of this tree variety to measure herbage trends. This information will be highly useful in anticipating needed adjustments in range stocking and predicting when it will no longer be practicable to graze in planted stands of trees.

Of significance in the development of the native range management research program is the extent to which native rangelands will be tapped for improved pastures and raising of truck crops.

Establishing improved pasture is expensive, but returns under good management and good markets generally have been satisfactory, particularly for raising steers and stock of high breeding. The possible addition of 1 million acres of improved pasture by 1964 will strengthen the need for studies leading toward better complementary use of native ranges and improved pastures. Studies specifically in this category currently are rated only of medium priority, however, because much of the needed knowledge can be obtained in management studies of herbage production, utilization, season of grazing, and others currently rated of higher priority.

Studies may be needed in grazing management of the approximate 100,000 acres handled under shifting agriculture each year. Over a 10-year period the native vegetation on approximately 1 million acres of rangeland will be destroyed and an invading plant cover will take its place. Most efficient grazing use of abandoned farm lands may be in conjunction with undisturbed native rangelands in some system of deferred-rotation grazing.

The Florida Agricultural Experiment Stations are exploring the feasibility of re-using this land in some system of vegetable crop-pasture rotation (19). Should this work prove successful, the effects of shifting agriculture on the native range will be lessened. In view of such a possibility, studies in developing management systems useful for abandoned cropland are rated of low priority.

An unknown but sizeable acreage of rangeland seeded to carpetgrass and other forage species is maintained at relatively low levels of productivity through lack of fertilization and other approved agronomic practices. Cattle frequently graze this seeded range along with unimproved native range. Studies leading to greater productivity from the seeded range through more desirable management systems can be of value. They should await results of management studies on unimproved native range.

Problems which have arisen from the kinds of range management employed: Preeminent among these problems, which have been fostered by lack of research in range management or failure to apply good recommendations, is the apparent overstocking of rangelands. Studies are needed to find how many head of cattle can be grazed per unit of range commensurate to proper use of range vegetation and

without disturbance to other land resources. Separate studies will be needed for the several major forage types supplemented by auxiliary studies to set up grazing capacities for different condition classes of the major types.

Studies in grazing capacity will be needed where fire is used. However, these studies should be accompanied by other work which sorts out the most desirable burning methods. Studies of grazing capacity on unburned rangeland are needed to obtain a true measure of the native range's potential productivity. Included will be studies on plant species composition, herbage production, and utilization, and other items, all of which are treated in detail in other paragraphs.

Studies of phenology and plant growth habits will be needed, followed by other studies to show when individual plant species can best stand grazing. Once the growth habits of individual plant species and their respective resistances to grazing have been found, season of use studies will be needed for the major plant communities. Management systems which would favor all species in a given community may be impractical to devise, so research must determine the important species to be favored through selected seasons of use.

Hand in hand with the season of use studies are studies in deferred-rotation grazing with and without burning. Fencing different range types and employing some system of deferred-rotation grazing between types might be most satisfactory. Maiden cane, an important and highly-palatable grass, and other desirable species might attain their highest productivity under this plan. However, because range types frequently are intermingled--with ponds, cypress strands, and pineland range all occurring in one large range unit--fencing of major types may prove impractical. Whatever systems of rotation-deferred grazing are tested, the resulting recommended method must prove practical from a fencing standpoint as well as applicable to the peculiar yearlong grazing periods which exist in south Florida.

Problems associated with livestock management: Research in Florida and elsewhere has provided good breeding practices applicable in the project area. Acceptance of good breeding practices already developed needs to be encouraged. This, of course, does not constitute a research need, but the full value of well developed range management systems cannot be realized unless accompanied by good cattle management including good breeding practices. Further study is needed to determine breeding practices most suitable under range conditions in the project area, and is given high priority.

Only a limited amount of information is available on performance and production by cattle grazing native ranges. Acceptance of range research results will depend greatly upon expected increased yields. Studies yielding data on cattle performance and production are thus considered of high priority.

The Florida Agricultural Experiment Stations have obtained valuable data on mineral needs and consumption. Because of this, mineral studies currently are rated of medium priority. South Florida ranges generally are well watered for 9 or 10 months of the year. Studies in cattle water requirements can be delayed until information on more urgent and higher priority management questions is made available.

Supplemental feeding of brood cows and creep feeding of calves on native range may prove highly important in attaining optimum beef cattle production. Information on the value of these practices is certainly needed, but studies must wait until basic management techniques are explored.

Parasitism of range cattle will result in reduced returns. Research by such agencies as the Florida Agricultural Experiment Stations has shown the value of parasite control. Additional study of parasites should be encouraged through cooperation with properly constituted agencies.

Problems engendered by the inherent range environment: The south Florida project area, in common with other major range areas and particularly with other parts of the Coastal Plain of the South, has range problems directly attributable to the environment. As previously pointed out, rainfall is high in summer and low in winter. A high percentage of the soils are sands of relatively low fertility which, although poorly drained, are drouthy during the winter dry periods.

Study is needed to determine whether concentration of livestock on unsubmerged range lands during high rainfall periods is detrimental to the range. If so, further work will be needed for obtaining better distribution. These studies should explore the practicability of fencing; they tie directly to studies of properly spacing water developments under south Florida climatic conditions.

Range plants growing on the sandy soils have been found deficient in some elements important to good animal nutrition. To achieve optimum production of beef from the native range, grazing management systems must take full advantage of the nutritive capabilities of range forage. Studies are needed to completely explore these capabilities, as well as the limitations of important forage plants.

Some nutritive analysis work has been done on pineland threeawn (Aristida stricta) in the project area (2, 4, 6). This work should be strengthened by extensive collection and analysis of herbage samples throughout the grazing year. Because the range vegetation is not limited to pineland threeawn but is made up of several hundred grazed forage species, nutritive analysis study should be extended to most of the range plants found to be important through plant abundance and palatability tests. Nutritive analysis study should include plants from both burned and unburned ranges. If plants are found which are especially desirable from a nutrition standpoint, studies should be undertaken to increase their abundance.

Problems in deer-cattle relationships: At present, deer populations are low in south Florida and generally no real competition exists between cattle and deer for forage. However, sportsmen's desires for increased numbers of shootable deer could conceivably favor large increases in deer numbers. Should this happen, problems in dual range use could arise. Studies in finding approved range management systems for cattle should anticipate need for possible future adjustments favoring integration of deer and cattle range use.

SCOPE OF RESEARCH

Problems will be studied which occur on or relate to forest rangelands both stocked and nonstocked with trees. Native prairie-type ranges adjacent to the forest lands and marshy rangelands intermingled with both forest and native prairie ranges are included in the problem field. Because of the present and probable future small numbers of other livestock which graze native range, only cattle and cattle management problems will be considered. The program will emphasize finding management systems applicable to cow and calf operations.

Some range problems outside the scope of Forest Service responsibilities are touched upon in the analysis because of their significance to the over-all range management program. Chemical and mechanical control of undesirable range plants is one example. Livestock management research is not strictly a Forest Service responsibility, but optimum use of rangelands requires good livestock management and justifies encouragement by the Forest Service of further development and application of best possible livestock management techniques. Although research in range seeding is not within Forest Service responsibilities, management of seeded range is, and problems in this field are discussed. Improved pasture research is within the scope only as it relates to research on native rangelands.

Where research or assistance is needed in fields outside the scope of Forest Service responsibilities to foster complete attainment of range management research objectives, the possibilities of cooperative effort will be explored with responsible groups. The scope of responsibility for agencies cooperating with the Forest Service will be closely defined prior to initiation of specific cooperative projects.

Need for cooperation is anticipated from the Agricultural Research Service of USDA and the Florida Agricultural Experiment Stations in problems relating to nutritional studies, native range grazing in relation to improved pastures, herbicidal or mechanical control of undesirable plants, animal response to grazing practice, supplemental feeding, animal diseases, and general animal husbandry aspects. In the event of future studies in cattle-deer relationships, cooperation will be desirable between the Forest Service and the Florida Game and Fresh Water Fish Commission. The Soil Conservation Service, USDA, may be called upon to assist with certain problems relating to soils.

PROPOSED PROGRAM

Problem	Relative importance	Urgency	Susceptibility to solution through research	Priority
I Problems in study of the range per se, and sampling techniques				
A. Collection and identification of important range plants	High	High	High	High
B. Phenology and growth habits of important range plants	High	High	Medium	High
C. Herbage production of important range plants	High	High	Medium	High
D. Nutritive values of important range plants (also listed under V)	High	Medium	Medium	Medium
E. Miscellaneous ecological studies				
1. Defining of south Florida range types	High	Medium	High	High
2. Range condition and trend studies	High	Medium	Medium	High
3. Autecology of saw-palmetto	High	High	Low	High
F. Control of saw-palmetto	High	Medium	Low	Medium
G. Efficient devices and techniques for sampling range vegetation	High	High	Medium	High
II Problems revolving around major past, present, and possible future land management practices				
A. Range burning				
1. Ecological aspects of burning on range vegetation and soils (the long-time effects)	High	High	Low	High
2. Develop improved burning methods				
a. Determine best seasons for burning	High	High	Medium	Medium
b. Proper time intervals between fires on same piece of range	Medium	Medium	Medium	Medium
c. Proper periods of grazing deferment following burning	High	High	Medium	Medium
d. Relations between degree of herbage utilization and species resistance to fire	Medium	Medium	Low	Medium
e. Effects of range fires on trees	Medium	Medium	Medium	Low
B. Ecological aspects of timber removal, past and future	Medium	Low	Low	Low

C. Determine practicability of and methods for integration of forestry and grazing	High	Medium	Medium	Medium
1. Effects of trees on range productivity	Medium	Medium	Medium	Low
2. Effects of grazing on tree growth	Low	Low	Medium	Low
D. Determine grazing management systems useful for seeded range	Medium	Medium	Medium	Medium
1. Ecological studies	Low	Low	Medium	Low
2. Herbage production and utilization studies	Medium	Medium	High	Medium
3. Practical management systems for:				
a. Seeded range alone	Medium	Medium	Medium	Medium
b. Seeded range in combination with native range	Medium	Medium	Medium	Medium
E. Develop better ways for complementary use between native range and improved pastures	Medium	Medium	Medium	Medium
F. Determine grazing management systems useful for abandoned crop land	Medium	Low	Medium	Low
1. Ecological studies	Low	Low	Medium	Low
2. Herbage production and utilization studies	Medium	Medium	High	Low
3. Practical management methods for:				
a. Abandoned cropland alone	Low	Low	Medium	Low
b. Abandoned cropland in combination with native range	Medium	Low	Medium	Low
III Problems resulting from kind of range management employed				
A. Determine optimum rate of range stocking for high sustained production of livestock without deterioration of range vegetation and soils through studies in grazing capacity	High	High	Medium	High
B. Proper seasons of use	High	High	Medium	High
C. Applicability of deferred-rotation grazing to south Florida ranges	High	Medium	Medium	Medium
IV Problems associated with livestock management				
A. Performance of brood cows on the native range under different systems of management	High	High	High	High

B. Animal production from the native range in terms of calf crop and weaning weight	High	High	High	High
C. Mineral requirements and consumption by beef cattle on native range	High	Medium	Medium	Medium
D. Water requirements of beef cattle on native range (also listed under V)	Medium	Medium	High	Medium
E. Improved cattle breeding practices for the native range	High	High	Medium	High
F. Values of supplemental feeding of brood cows or creep feeding of calves on native range	High	Medium	Medium	Medium
G. Effects of parasites on range cattle, including values of certain control techniques	High	Medium	Medium	Medium
V Problems engendered by the inherent range environment				
A. Effects on range as a result of livestock concentration during high water periods.	Medium	Medium	Medium	Medium
B. Water requirements for cattle and proper spacing of water developments on dry-period ranges	Medium	Medium	High	Medium
C. Nutritive values of important range plants	High	Medium	Medium	Medium
VI Problems in native range, cattle-deer relationships				
A. Competition between cattle and deer for forage	Low	Low	Low	Low
B. Effects of prescribed burning on deer habitat	Medium	Low	Medium	Low
C. Range and cattle management systems favoring integration of deer production with cattle	Medium	Low	Medium	Low

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APPENDIX

Table 3.--Ownership of land in south Florida project area, 1949 1/

Class of ownership	Land area	
	Acres	Percent
Public land		
Federal		
National forest	70,300	0.4
Indian	78,500	0.4
Other Federal	1,036,400	5.9
Total Federal	1,185,200	6.7
State	960,000	5.5
County and municipal	105,000	0.6
Total public	2,250,200	12.8
Private land	15,382,900	87.2
Total all ownership	17,633,100	100.0

1/. Data from McCormack (44, 45)

Table 4.--Grazing lands in south Florida

Kind	Amount
	Acres
Forest land 1/	
Pine	5,661,300
Hardwoods	1,575,000
Palm	129,600
Nonproductive forest 2/	835,700
Total grazeable forest land	8,201,600
Treeless prairie 3/	2,000,000
Improved pasture 4/	1,000,000
All grazing land	11,201,600

1/ Data from McCormack (44, 45)
2/ McCormack's 1,335,700 less 500,000 acres for ungrazeable, nonproductive forests.
3/ Estimated by Rummell.
4/ Estimated by Florida Agricultural Experimental Station personnel.

Table 5.--Appro[illegible] of land planted

Planting period	So. Florida project area	State of Florida
1928 - 53	22,285	287,544
1953 - 54	140	107,020
1954 - 55	575	95,606
1928 - 55	38,000	490,170

2/ Adjusted to compensate for discrepancy between totals issued in 1954 summary for Volusia County for period 1928-54 and totals given in 1955 summary for 1928-54 period.

Table 7.--Cows per bull on differe[illegible] 1/

[illegible]	[illegible]	[illegible]	[illegible]
Flatwoods	-	83	33
Prairie	-	-	34
Hammock	12	43	31
Blackjack	16	34	30

1/ Data from Camp (6).

Table 8.--Average calf crop for 1935, 1940 and 1947 reported by 19 large and 15 small Florida ranchers in 1948 1/

Year	Ranch 3,200 acres and over	Ranch less than 3,200 acres
	Percent	Percent
1935	42.0	48.0
1940	50.0	59.0
1947	57.0	75.0

1/ Data from Parvin (49).

Table 6.--Estimated deer population by county in south Florida 1/

County	Population
	Number
Citrus	1,000
Sumter	130
Seminole	800
Brevard	500
Orange	850
Hernando	180
Pasco	160
Polk	250
Osceola	1,400
Lake	350
Hillsborough	10
Pinellas	--
Manatee	20
Sarasota	25
DeSoto	35
Highlands	230
Okeechobee	170
Indian River	150
St. Lucie	200
Martin	130
Palm Beach	150
Glades	80
Hendry	350
Charlotte	500
Lee	800
Collier	1,800
Broward	450
Dade	500
Monroe	1,300
Hardee	50
Total	12,570

1/ Personal communication from E. B. Chamberlain, Jr., Chief, Game Division, Florida Game and Fresh Water Fish Commission (August 19, 1955).

Table 9.--Minimum, maximum and average percentage calf crop on four types of ranges in Alachua County [1]

Range type	Minimum	Maximum	Average
	Percentage calf crop		
Flatwoods	20	50	34.4
Prairie	20	75	54.1
Hammock	20	90	71.6
Blackjack	15	100	37.1

1/ Data from Camp (6).

Table 10.--Weights of calves at 6 months of age [1]

Breeding	Ranch 3,200 acres and over		Ranch less than 3,200 acres	
	Cattlemen reporting	Weight	Cattlemen reporting	Weight
	Number	Pounds	Number	Pounds
Grade bull X native cow	10	230	4	231
Purebred bull X native cow	18	261	9	283
Purebred bull X grade cow	19	312	26	327
Purebred bull X purebred cow	3	342	3	342

1/ Data from Parvin (49).

Table 11.--Classes and grades of cattle sold in five south Florida markets in 1954 [1]

Grade	Steers	Heifers	Cows	Bulls	Calves	Total	
	Number	Number	Number	Number	Number	Number	Percent
SLAUGHTER ANIMALS							
Prime	0	0	--	--	0	0	0
Choice	2	0	0	0	67	69	0.1
Good	132	5	0	0	3,933	4,070	5.3
Commercial	1,677	368	175	53	8,815	11,088	14.5
Utility	5,769	1,512	3,960	856	16,297	28,394	37.2
Cutter	3,617	2,362	7,695	1,302	--	14,976	19.6
Canner	1,265	531	7,343	604	--	9,743	12.8
Cull	--	--	--	--	7,965	7,965	10.4
Total slaughter	12,462	4,778	19,173	2,815	37,077	76,305	99.9
STOCKER ANIMALS							
Fancy	0	0	0	0	0	0	0
Choice	0	0	0	0	0	0	0
Good	23	0	0	0	17	40	0.1
Medium	1,059	215	9	75	485	1,843	5.1
Common	8,968	2,627	920	445	3,769	16,729	46.3
Inferior	4,834	3,000	3,584	394	5,668	17,480	48.4
Total stocker	14,884	5,842	4,513	914	9,939	36,092	99.9

1/ Data compiled from Rhodes (52).

Table 12.--Beef cattle by class, January 1, 1955

Class	Entire State [1]	Estimates for project area [2]
	Number	Number
Steers	184,000	134,000
Heifers (1-2 yrs)	162,000	118,000
Calves	207,000	150,000
Cows	777,000	565,000
Bulls	46,000	33,000
Total	1,376,000	[3] 1,000,000

1/ Data from Rhodes (53).
2/ Proportionate to State class figures.
3/ Computed by Rummell

Table 13.--Estimated average grazing capacity of four types of native range in Alachua County, Florida [1]

Type of range	Range per animal per year
	Acres
Flatwoods	10
Prairie	1
Hammock	5
Blackjack	22

1/ From Camp (6).

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Time of Flowering and Seed Ripening in Southern Pines

by

Keith W. Dorman

and John C. Barber

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

in cooperation with
GEORGIA FOREST
RESEARCH COUNCIL

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

FOREWORD

This publication was prepared under the sponsorship of the Committee on Southern Forest Tree Improvement by the Subcommittee on Tree Selection and Breeding. It is the purpose of the Committee: to advise and assist those interested in the improvement of southern forest trees in arranging and conducting research and development programs; to provide a clearing house for information on forest tree improvements; to provide for or assist in coordination in the conduct of a Southwide program of tree improvement research and development; and to foster and encourage the advancement of knowledge of southern tree genetics.

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TIME OF FLOWERING AND SEED RIPENING IN SOUTHERN PINES

by

Keith W. Dorman and John C. Barber
Athens-Macon Research Center, Macon, Georgia

INTRODUCTION

Accurate knowledge of the time of year when pine flowers and seeds ripen is of vital importance to forest tree breeders and foresters responsible for seed procurement. The recent rise in interest and activity in breeding southern yellow pines has pointed up the fact that very little is known about the pattern of flower development and seed ripening for each species over the South. Certainly the need for this information is great. Seedlings of the southern yellow pines are being planted in astronomical numbers--over 300 million in 1954. Selection of superior individual trees and races, controlled pollination within and between species, and studies of inheritance of good and bad traits are being carried on by many workers in the South. Seed orchards are being established with grafted stock of outstanding wild trees. Seed, pollen, and scion material are being widely exchanged by technicians in tree genetics who could much better plan their cooperative work if they knew the time of flowering and seed ripening throughout the 200 million acres of the southern pine area extending from Virginia to Texas.

For such reasons, under the sponsorship of the Southern Tree Improvement Committee, forms for reporting pollen and seed ripening data were sent in January 1954 to forest research personnel at experimental forests and other research stations throughout the South. Cooperators were asked to report data for 1954 and other records that might be available. The response to the questionnaire was excellent. Data were obtained for many locations over the geographic range of the major southern pines. However, the data were very scarce for minor species, and additional observations will be required before accurate dates of flowering and seed ripening are determined for all parts of the range.

EARLY OBSERVATIONS ON PHENOLOGY OF FOREST TREES

Interest of botanists in phenology, which can be defined as the science of the relations between climate and periodic biological phenomena, has been active for years. In 1915, Lamb (6) published in chart form for a great many species the time of leafing, full foliage, flowering, seed ripening, seed falling, and leaf falling. In 1953, Duffield (4) revised an earlier publication, giving pine pollen collection dates with data on annual and geographic variation based on observation at the Institute of Forest Genetics in California. He states that Pinus ponderosa on the west slope of the Sierra Nevada show a difference of 8

days in pollen collection per 1,000-feet difference in elevation, and that his figure agrees moderately well with Hopkins' (5) constant of 4 days for each 400-feet difference in elevation. The order of bloom of trees and shrubs at the Arnold Arboretum has been given by Wyman (15). A method for describing and comparing blooming seasons has been given by Anderson and Hubricht (1).

In the northeast, Wright (13) reported date of flowering of a large number of hardwood and softwood species for 1947 through 1951. He states that there was a slight telescoping of the over-all flowering season in years when flowering started late. The telescoping was not equal for all species or all portions of the flowering season, because weather during and before the season influenced flowering. The spread in flowering time within species was greatest in the early-flowering maples and ashes. This spread varied from 0 to 2 weeks in different years. Much of the spread was associated with location of the trees. But in all species half or more of the spread occurred within rather small groups of trees. In most species, extreme cases of earliness or lateness remained constant from year-to-year, whereas trees differing by only a few days often shifted their relative order in flowering. He also reviews published phenological records for the Northeast and Lake States.

In Australia, Millett (9) observed that air and soil temperatures were associated with the first ripening of male flowers of Monterey pine. Also, he found that the extension of the pollen season beyond the initial ripening stage was more closely related to sunshine, evaporation, and wind than to other meteorologic factors. Leven (7) discussed for European and Japanese larch the effects on flowering of frost, longitude, latitude, altitude, aspect, exposure, and age of tree. The duration of flowering at 17 stations in Scotland is given for both species of larch as well as the earliest dates of flowering for each between 1924 and 1943. Sarvas (10) discussed at length the biology of flowering in Betula verrucosa Ehrh. and Betula pubescens Ehrh. and established the general course of the annual and daily cycle of pollination.

Numerous observations on flowering and seed ripening have been made in the South. Coker and Totten (2) mention time of pollen shedding for some of the trees described in their book. Dorman, et al.[1/] recorded time of pollen shedding and female flower receptivity for slash and longleaf pine used in breeding for improved gum yields at Lake City, Florida. For slash pine pollen shedding began about February 1 and extended to February 20, but varied from year-to-year. Also, some trees were consistently earlier than others in time of flowering.

In Texas, Zobel and Goddard (16) found that in general slash pine is pollinated from the latter part of January to early in February, loblolly pine and longleaf pine from late February to the middle of March, and shortleaf pine from late March to early in April. They also found variation in time of blooming and seed ripening between trees and between seasons.

1/ Unpublished office reports of the tree-breeding project on file at the Lake City Research Center, Lake City, Florida.

The relation between stages of flower development and various operations in controlled pollination of trees has been discussed for slash pine by Snow, Dorman, and Schopmeyer (11); for northeastern hardwood and softwood species by Wright (14); and for pines in California by Cumming and Righter (3).

Ripening of southern pine seed varies from year to year, but probably greater variation occurs in cone opening, because of variable humidity (16). Based on observations from Georgia, and from Florida to Texas, slash pine cones mature from September 1 to 10; loblolly, September 20 to October 10; and longleaf and shortleaf, October 1 to 20 (12).

POLLEN AND SEED RIPENING DATES FOR SOUTHERN PINES IN 1954

This paper reports data for 1954 for the major species of southern pine and less completely for the minor species. Data for pines growing in the Southern Appalachians are included.

Observations on time of pollen and seed ripening are given in tables 1 through 5. Where dates were reported as early, middle, or late in the month, they were converted to the 5th, 15th, and 25th, respectively, to create uniformity in the tables. The questionnaire suggested that the general period of pollen ripening and other dates be reported in general terms; however, actual day and month were reported in most instances. The location was reported by county or parish. The latitude was read from maps, so the fractional part of a degree should be regarded as an approximation.

The data show a consistent pattern over the South in the sequence of bloom, with slash pine first, followed by longleaf, loblolly, and shortleaf.

Slash pine, with the most limited geographic range, varied least in time of pollen ripening, although the earliest reported in Alachua County, Florida, was January 20, and the latest, February 21, from a plantation of unknown source in Rapides Parish, Louisiana. Seed ripening was estimated to vary between September 1 to 15.

Longleaf pine pollen was reported ripening February 5 in Alachua County, Florida, and April 16 at Hertford County, North Carolina, which is near the northern extension of the natural range. In Jefferson County, Alabama, at an elevation of 500 feet, pollen was ripe March 20. Over a wide range, seed ripened September 10 to mid-October.

In loblolly and shortleaf pine, a similar pattern of time of bloom in relation to latitude and elevation occurred. In Berkeley County, South Carolina, which is near the coast at an elevation of about 40 feet, loblolly pollen ripened March 1. In Union County, where the elevation was 800 feet, it ripened April 1. Shortleaf pine pollen ripened March 7 and April 16 at the same stations. Seed ripened between September 20 and October 20 for both species.

Table 1.--Slash pine flowering and seed ripening dates in 1954 by state, county, latitude, and elevation

State	County	North latitude	Elevation	Pollen ripening		Seed ripening	
				Start	End	Start	End
		Degrees	Feet	Date			
South Carolina [1]	Georgetown	33° 25'	--	2-10	--	--	--
Georgia	Dooly	32° 0'	350	2-2	2-25	9-15	10-5
Florida	Columbia	30° 20'	200	1-27	2-15	9-1	10-12
Florida	Alachua	29° 35'	155	1-21	--	9-14	--
Florida [2]	Hendry	26° 40'	30	1-20	2-20	9-5	11-1
Alabama	Escambia	31° 0'	200	1-25	2-5	9-25	10-15
Mississippi	Harrison	30° 40'	228	2-1	2-9	9-15	--
Louisiana [1]	Rapides	31° 10'	200-300	[3] 2-1	2-12	9-15	--
Louisiana [1]	Rapides	31° 10'	200-300	[3] 2-21	--	9-15	--
Arkansas [1]	Ashley	33° 5'	175	2-16	2-26	9-15	10-5
Texas [1]	Newton	30° 55'	100	1-25	2-15	9-15	10-15

1/ Plantation, source of seed unknown.
2/ South Florida slash pine (Pinus elliottii var. densa).
3/ For 1951 season.

Table 2.--Longleaf pine flowering and seed ripening dates in 1954 by state, county, latitude, and elevation

State	County	North latitude	Elevation	Pollen ripening		Seed ripening	
				Start	End	Start	End
		Degrees	Feet	Date			
North Carolina	Hertford	36° 30'	40	4-16	4-22	--	--
South Carolina	Georgetown	33° 25'	--	3-12	--	--	--
South Carolina	Berkeley	33° 25'	30	3-7	3-17	9-10	10-1
Georgia	Dooly	32° 0'	350	2-25	3-26	10-1	10-30
Florida	Columbia	30° 20'	200	2-15	3-1	10-1	11-1
Florida	Alachua	29° 35'	155	2-5	3-1	--	--
Alabama	Jefferson	33° 35'	500	3-20	4-5	--	--
Alabama	Escambia	31° 0'	250	2-23	3-15	10-15	11-10
Mississippi	Harrison	30° 40'	228	2-16	3-11	10-15	--
Louisiana	Rapides	31° 10'	200-300	[2] 2-21	3-15	[1] 10-15	--
Louisiana	Rapides	31° 10'	200-300	[2] 3-2	--	10-18	--
Arkansas [3]	Ashley	33° 5'	175	3-13	3-25	10-5	10-25
Texas	San Augustine	31° 20'	--	--	3-12	--	--
Texas	Newton	30° 55'	100	3-15	3-25	10-5	10-25

1/ Average of 1949 to 1952.
2/ For 1951 season
3/ Plantation, source of seed unknown.

Table 3.--Loblolly pine flowering and seed ripening dates in 1954 by state, county, latitude, and elevation

State	County	North latitude	Elevation	Pollen ripening		Seed ripening	
				Start	End	Start	End
		Degrees	Feet	Date			
North Carolina	Hertford	36° 30'	40	4-6	4-15	--	11-1
South Carolina	Georgetown	33° 25'	--	3-2	--	--	--
South Carolina	Berkeley	33° 25'	30	3-1	3-15	9-20	10-15
South Carolina	Union	34° 40'	800	4-1	4-7	10-15	--
South Carolina	Union	34° 40'	800	1/ 4-16	4-23	10-15	--
Georgia	Dooly	32° 0'	350	3-8	3-27	10-10	11-15
Florida	Alachua	29° 35'	155	2-20	3-16	--	--
Alabama	Jefferson	33° 35'	500	3-20	4-5	10-15	--
Alabama	Escambia	31° 0'	150	3-8	4-1	--	--
Mississippi	Harrison	30° 40'	228	2-22	3-11	--	--
Louisiana	Rapides	31° 10'	200-300	2-21	3-15	--	--
Louisiana	Rapides	31° 10'	200-300	1/ 3-4	--	2/ 10-17	--
Arkansas	Ashley	33° 5'	175	3-12	3-30	10-5	10-25
Texas	Nacogdoches	31° 35'	300	3-1	3-26	--	--
Texas	Montgomery	30° 20'	150	3-5	3-30	3/ 10-1	10-15
Texas	Angelina	31° 20'	250	2-25	3-20	3/ 10-3	10-20
Texas	Bastrop	30° 5'	200	2-12	3-11	3/ 9-28	10-15

1/ For 1951 season.
2/ For 1950 season.
3/ For 1953 season.

Table 4.--Shortleaf pine flowering and seed ripening dates in 1954 by state, county, latitude, and elevation

State	County	North latitude	Elevation	Pollen ripening		Seed ripening	
				Start	End	Start	End
		Degrees	Feet	Date			
North Carolina	Hertford	36° 30'	40	4-24	4-29	--	--
North Carolina	Durham	36° 0'	--	4-16	5-5	10-1	10-18
North Carolina	Buncombe	35° 35'	2300	5-5	5-18	10-20	11-1
South Carolina	Berkeley	33° 25'	30	3-27	4-7	--	--
South Carolina	Union	34° 40'	800	4-16	4-23	10-25	--
South Carolina	Union	34° 40'	800	1/ 4-26	--	--	--
Alabama	Jefferson	33° 35'	500	4-1	4-15	--	--
Mississippi	Harrison	30° 40'	228	3-26	4-7	--	--
Mississippi	Lafayette	34° 10'	450	4-2	4-16	10-15	11-1
Louisiana	Rapides	31° 10'	200-300	3-27	4-8	2/ 10-17	--
Louisiana	Rapides	31° 10'	200-300	1/ 3-30	--	--	--
Arkansas	Boone	36° 10'	1200	4-15	5-13	1/ 10-10	1/ 11-15
Arkansas	Ashley	33° 5'	175	4-1	4-10	10-15	11-5
Texas	Nacogdoches	31° 35'	300	3-20	4-15	--	--
Texas	Angelina	31° 20'	250	3-25	4-5	10-15	10-25

1/ For 1951 season.
2/ For 1952 season.

Table 5.--Dates of flowering and seed ripening in 1954 for Appalachian Mountain and minor species of southern pine

Pine species	State	County	Elevation	Pollen ripening		Seed ripening	
				Start	End	Start	End
			Feet	Date			
Pond	North Carolina	Hertford	40	5-1	5-5	--	--
Pond	South Carolina	Georgetown	--	4-7	--	--	--
Pond	Florida	Columbia	200	3-24	--	--	--
Virginia	North Carolina	Buncombe	2300	4-29	--	--	--
Virginia	Alabama	Jefferson	500	3-15	3-30	--	--
Virginia 1/	Mississippi	Lafayette	450	3-30	4-19	--	--
Pitch	North Carolina	Buncombe	2300	4-29	2/ 5-11	--	--
Table-Mountain	North Carolina	Buncombe	2300	4-8	4-20	10-20	--
Spruce	South Carolina	Berkeley	30	3-15	--	--	--
Spruce	Mississippi	Harrison	228	2-23	3-7	10-25	--
Sand	Florida	--	--	12-25	1-25	--	--
Eastern white	North Carolina	Buncombe	2300	5-29	6-15	--	--

1/ Plantation, seed source unknown.
2/ Pollen in full flight.

VARIATION IN POLLEN AND SEED RIPENING IN RELATION TO LATITUDE

Time of pollen ripening in southern pines is strongly related to latitude, as shown in figures 1 through 3. This relation holds true for slash pine although the species occurs over a relatively narrow range in latitude. Slash pine plantations of unknown seed source apparently follow the same trend as wild stands. Longleaf, loblolly, and shortleaf pine pollen may ripen over a period of 2 weeks in the same latitude. Elevation becomes a factor here, and also proximity to the seacoast. However, the variation does not appear to be greater than what might be expected in year-to-year variation or tree-to-tree variation in the same stand. An exception to this generalization might occur in mountain stands as compared with others. Buncombe County, North Carolina, has elevations in excess of 2300 feet, and shortleaf pine reportedly blooms 3 weeks later than in the Piedmont.

Seed ripening occurs over a period of about 3 weeks for widely distributed species such as shortleaf, loblolly, and longleaf pine, and does not appear to vary greatly with latitude. Slash pine seems to vary little although two reports fell outside the general pattern. It should be kept in mind that seed ripening is difficult to observe and that considerable variation can be expected in data from different sources.

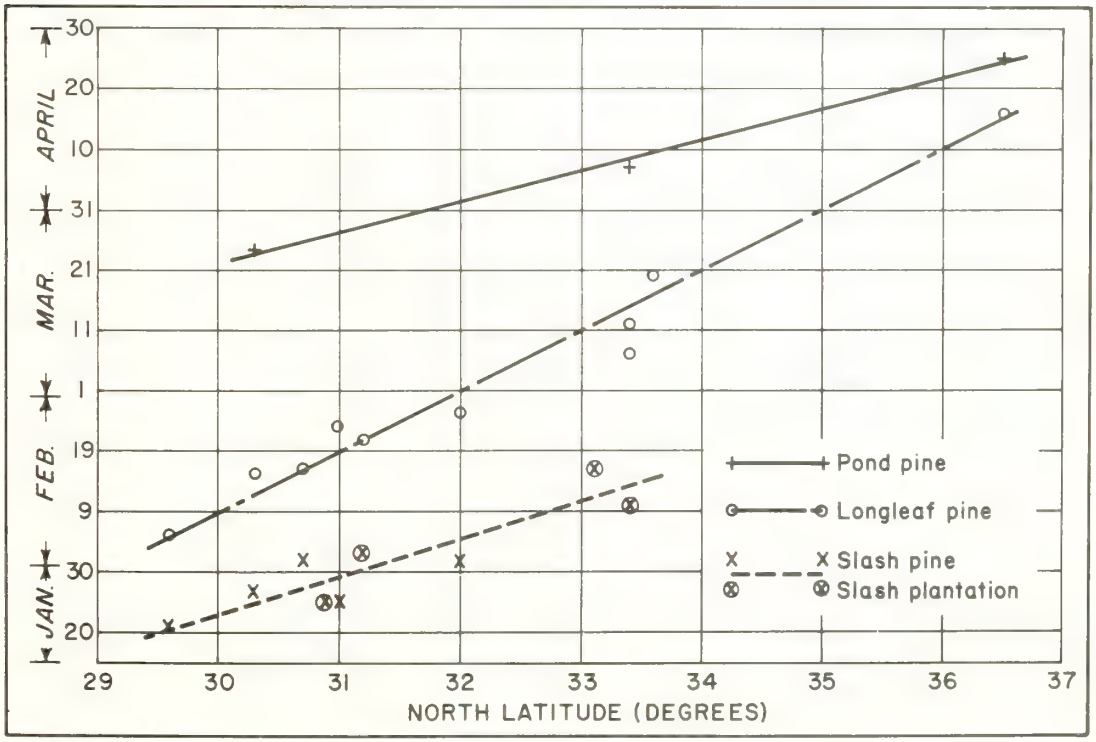

Figure 1.--Pollen ripening of pond, longleaf, and slash pine in relation to latitude.

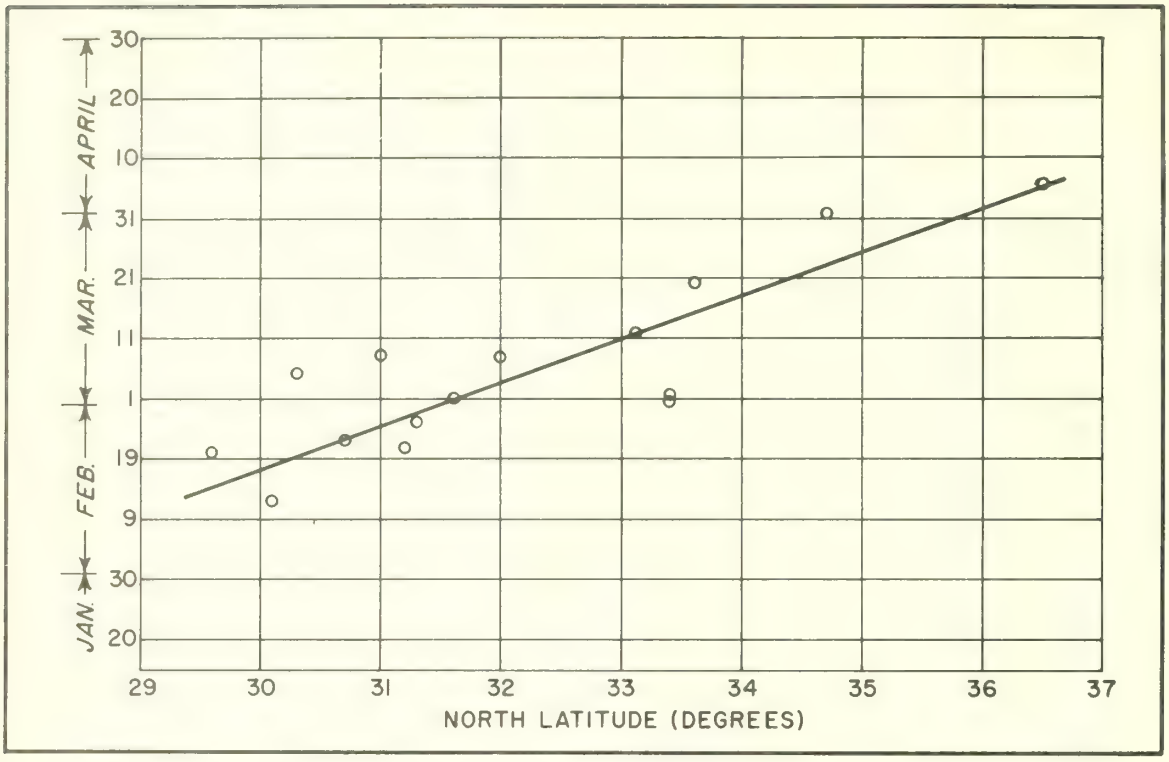

Figure 2.--Pollen ripening of loblolly pine in relation to latitude.

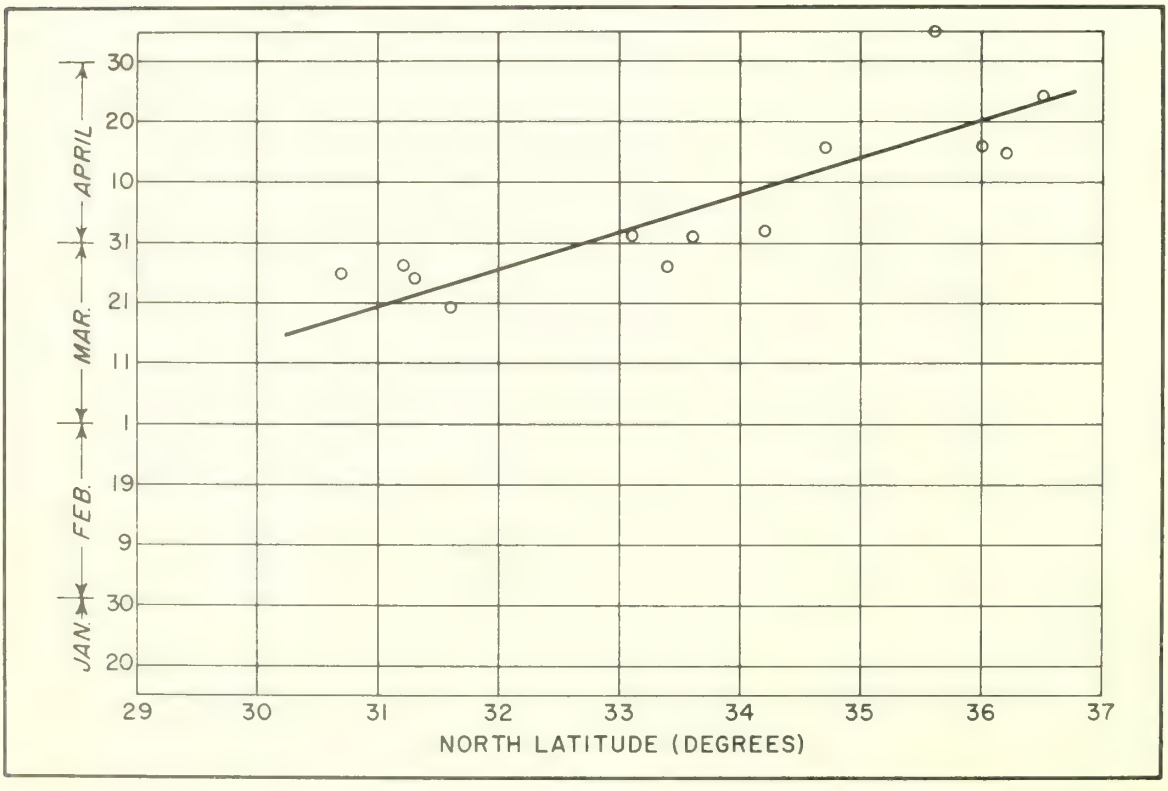

Figure 3.--Pollen ripening of shortleaf pine in relation to latitude.

VARIATION IN POLLEN RIPENING BETWEEN YEARS AND BETWEEN STANDS

At Franklin, Virginia, in the Bigwoods Experimental Forest, loblolly pine pollen was first noted on the following dates from 1948 through 1954:

Year	Date
1948	4-2
1949	3-27
1950	4-4
1951	4-12
1952	4-10
1953	3-30
1954	4-6

At the Lake City Research Center, records of stage of flower development have been kept during the pollinating season for trees in the tree breeding project. Records for a tree in Clinch County, Georgia, and a tree 10 miles south of Lake City in Columbia County, Florida, are given in table 6. These trees are about 70 miles apart. Time of pollen ripening did not vary widely between the two areas or between years except that 1949 was somewhat earlier than others.

Table 6.--Dates of pollen collection from single slash pine trees in south Georgia and northern Florida

Year	Clinch County, Georgia		Columbia County, Florida	
	Pollen ripe	Pollen shed	Pollen ripe	Pollen shed
	Date	Date	Date	Date
1943	2-2	2-12	--	--
1944	2-5	2-21	2-2	2-15
1946	2-4	--	1-23	2-11
1947	--	--	1-24	2-7
1949	1-19	--	1-21	--

In Florida, T. O. Perry [4/] observed that within a 15-mile radius of Gainesville there is a 3-week stand-to-stand spread in the time of flowering for any given species. In 1953, on the Austin Cary Forest, one stand flowered on February 5 and the other on February 20. These two stands were less than 3 miles apart. He also reported that during the spring of 1954, there was ample overlapping in the time of flowering so that slash pollen could fall on receptive longleaf conelets, and longleaf pollen could fall on receptive loblolly conelets.

4/ Personal communication.

VARIATION IN POLLEN RIPENING BETWEEN SPECIES

Table 7 gives the time of pollen ripening for six species of southern pines growing at the Institute of Forest Genetics in California. At 2700 feet elevation, time of bloom in slash pine was much later than in the South. Shortleaf and loblolly pine ripened their pollen about the same time as in areas in the upper South. However, the ending date in some cases was much later. Table 8 shows time of pollen ripening in 1954 for the major species of southern pines at the Southern Institute of Forest Genetics in Mississippi.

Table 7.--Time of pollen ripening for major species of southern pines at 2700 feet elevation at the Institute of Forest Genetics in California

Pine species	Pollen ripening period	
	Start	End
	Date	Date
Shortleaf pine	4-3	4-23
Loblolly pine	3-23	5-10
Slash pine	1/ 3-31	--
Longleaf pine	(2/)	--
Virginia pine	4-11	4-23
Pitch pine	4-8	4-29
Spruce pine	4-15	--

1/ Average pollen collection date.
2/ None produced to date by 20-year-old trees.

Table 8.--Time of pollen ripening for major species of southern pines at the Southern Institute of Forest Genetics at Mississippi

Pine species	Pollen ripening period	
	Start	End
	Date	Date
Slash pine	2-1	2-9
Longleaf pine	2-16	3-11
Loblolly pine	2-22	3-11
Shortleaf pine	3-26	4-7

DISCUSSION

A knowledge of time of pollen and seed ripening in southern pines will help tree improvement workers to plan field work and arrange for the exchange of pollen and seed. It should be remembered that the time of ripening may vary as much as 3 weeks between years and between trees in the same stand. Therefore, the need for pollen and seed should be anticipated as far in advance as possible and arrangements for obtaining it made accordingly.

Pollen and seed are more easily extracted if the male strobilus and cones are picked just prior to the time they would open on the tree. If it is not possible to collect at this time, then the earliest collection time that will give viable material becomes important. In California, where trees used for breeding at the Institute of Forest Genetics are sometimes located in inaccessible places, Cumming and Righter (3) suggest that if aceto-carmine smears show that pollen grains have completed the second division in the development of the gametophyte (remnants of two prothallial cells will be visible), the male strobilus will ripen after picking; but those collected prior to that stage may not ripen. A field microscope is required for this examination. The time at which pollen of various species of southern pine in the South could be collected, based on stage of development of the gametophyte, is unknown. However, it is expected that this information will be forthcoming as a result of studies in flower development now being undertaken.

Viable seed can be obtained from cones collected in advance of the normal time of opening, but extraction may require removal of the cone scales by hand. Wakeley (12) states that southern pine cones with a specific gravity of 0.89 are still closed, but that they have matured enough to open if picked and dried. He reports that cones on the tree usually open at a specific gravity of about 0.70. The time of year at which cones can be collected and viable seed obtained, even with hand extraction, should be determined for the major species of southern pine. Early collection of hand-pollinated cones would reduce the possibility of loss to squirrels and premature opening on the tree, and remove the necessity for bagging the cones on the tree. Also, the cone collecting season will be lengthened.

Seed of closed cone species, such as pond, sand, and Table-Mountain pine can be collected at any time, but viability is apt to be highest for seed of the current year. Cones of these species can be opened by soaking them briefly in hot water (8).

Sand pine and South Florida slash pine commonly form conelets at several periods during the spring. The conelets, and later the cones, appear in successive whorls at short intervals along the twigs. The interval between cones of different years is much longer. Formation of male strobili at more than one period has not been reported. Thus, late-blooming conelets are apt to have poorly-filled seed.

SUMMARY

Approximate dates of pollen and seed ripening have been tabulated for slash, longleaf, loblolly, and shortleaf pines for many stations throughout the natural ranges of the species. Similar data at a few stations have also been reported for the minor southern pines and the pines of the Appalachian Mountains.

In Alachua County, Florida (Gainesville), latitude 29° 35' N., slash pine pollen was ripe January 21. In Dooly County, Georgia (Cordele), latitude 32° 0' N., it was ripe by February 2. Longleaf pine in Alachua County, Florida, was ripe February 5, and in Hertford County, North Carolina (Murfreesboro), about latitude 30° 30' N., it wasn't ripe until April 16, or nearly 6 weeks later. Loblolly pine in Alachua County, Florida, was ripe February 25, and in Hertford County, North Carolina, April 4, about 6 weeks later. Shortleaf pine at Harrison County, Mississippi (Gulfport), latitude 30° 40' N., was ripe about March 25, and at Hertford County, North Carolina, around April 25 or about 4 weeks later.

Slash pine seed ripened about September 15; longleaf pine, October 1 through 20; loblolly pine, October 5 through 15; and shortleaf pine, October 15 through 30. No strong relationship with latitude was indicated, but it might have been obscured by the difficulty of observing when seed was ripe.

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PUBLICATIONS AND REPORTS PREPARED IN COOPERATION WITH THE COMMITTEE ON SOUTHERN FOREST TREE IMPROVEMENT:

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Agriculture--Asheville

ation Paper No. 73 November 1956

An Inexpensive Method for Measuring Charcoal Kiln Temperatures

by Ralph Peter

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

This study was made in cooperation with the U.S. Forest Products Laboratory, Madison, Wisconsin, and the George Foster Peabody School of Forestry, University of Georgia, Athens, Georgia. Grateful acknowledgement is extended to B. C. Haynes, of ARS, USDA, and the University of Georgia, for assistance in instrumentation.

AN INEXPENSIVE METHOD FOR MEASURING CHARCOAL KILN TEMPERATURES

by

Ralph Peter
Athens-Macon Research Center

During the production of charcoal in a cinder block kiln, it is important to control kiln temperatures, not only for the consistent production of quality charcoal, but also for the prevention of kiln deterioration due to excessive kiln temperatures. The present coaling procedures are based primarily on the color and volume of chimney smoke and on past operating experience gained by trial and error. Except possibly at the very extreme coaling conditions, color and smoke volume are not indicative of internal kiln temperatures. Temperatures have generally not been measured in production kilns because of the high cost of the equipment required and because of the relative inconvenience of instrument adjustments, use and care.

Tests have been made in the experimental 7-cord charcoal kiln located at Athens, Georgia, using an inexpensive standard brand D.C. microameter to measure kiln temperatures. After the instrument was calibrated to suit charcoaling conditions, it was tested during kiln operations. Good temperature comparisons were obtained between this inexpensive instrument and an accurate temperature compensating potentiometer, thus indicating that simple-to-operate, inexpensive equipment can be used.

Meter Calibration

The microameter when purchased is calibrated for microamps only. The new temperature scale drawn for the instrument is illustrated in figure 1. Copies included at the end of this report may be cut out and rubber-cemented directly over the scale furnished with the instrument to provide a reasonably accurate thermocouple pyrometer.

The temperature reading obtained with this instrument is the temperature difference between the actual kiln temperature and the temperature of the reference junction (fig. 2). The calibrations were made using 75° F. as an average reference junction temperature, or, in other words, average air temperature. For accurate kiln temperature readings, when the reference junction temperature is above 75° F. (use thermometer), add the difference between the reference junction temperature and 75° F. to the kiln temperature reading. If the reference junction temperature is below 75° F., subtract the difference. However, for charcoal kiln operations under average weather conditions this temperature correction may be omitted if desired. For extreme atmospheric temperatures, particularly winter conditions, the temperature corrections should be made.

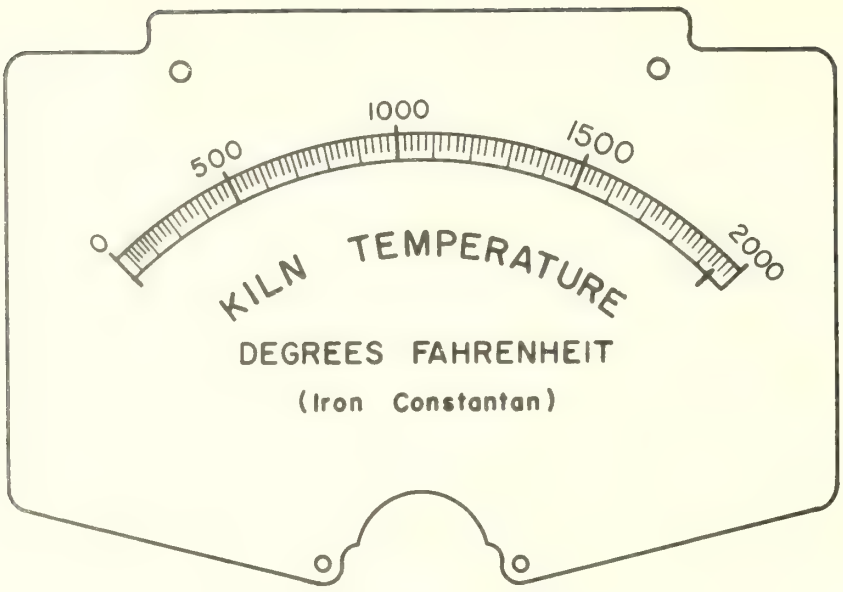


Figure 1.--New temperature scale.

Meter Requirements

The meter recommended should have a D. C. microameter range of 0 to 25 microamperes, and resistance of 2200 ohms.

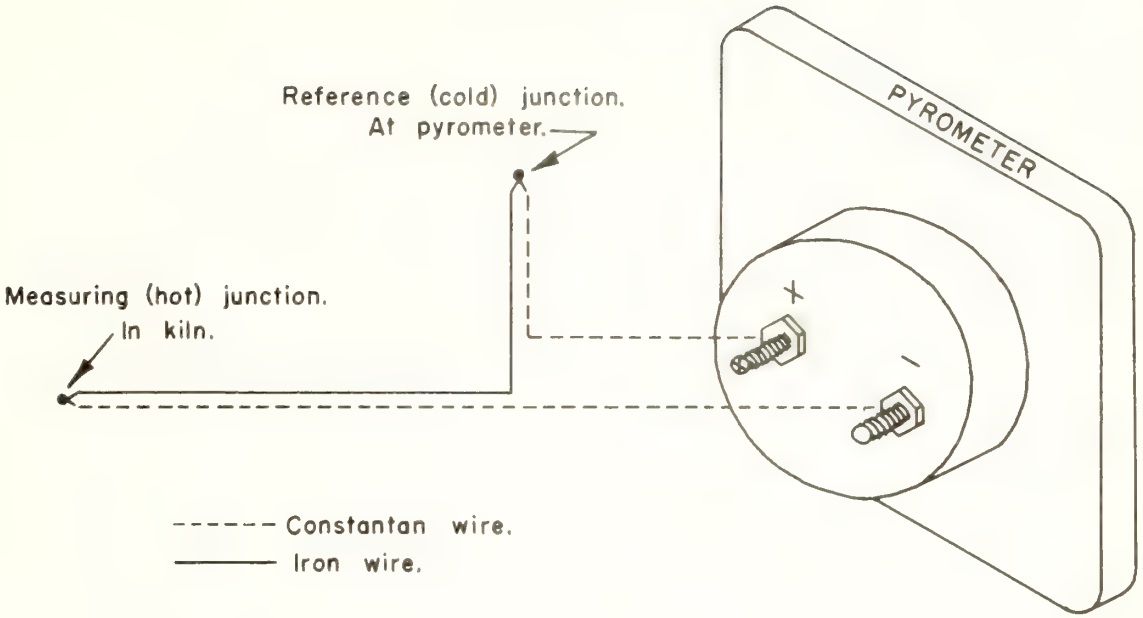
The scale furnished with the meter should be of the same size and shape as the scale shown in figure 1. The new scale cannot be substituted if the meter characteristics are different from the stated requirements.

Changing Scale

If the recommended meter is used, changing the scale is a simple matter. First remove the four recessed screws which hold the front cover of the instrument in place. Second, remove the four screws which fasten the scale plate to the meter case. Carefully slide the scale plate out from under the pointer without touching the pointer. Turn it over and rubber-cement the new scale (figure 1) to the back side. Replace the scale plate with the new scale showing, and carefully replace all screws in the inverse order to which they were removed.

Wire Requirements

The wiring system for measuring charcoal kiln temperatures is divided into two classifications. The wire located inside the kiln is called thermocouple wire, and the portion of the system on the outside of the kiln leading



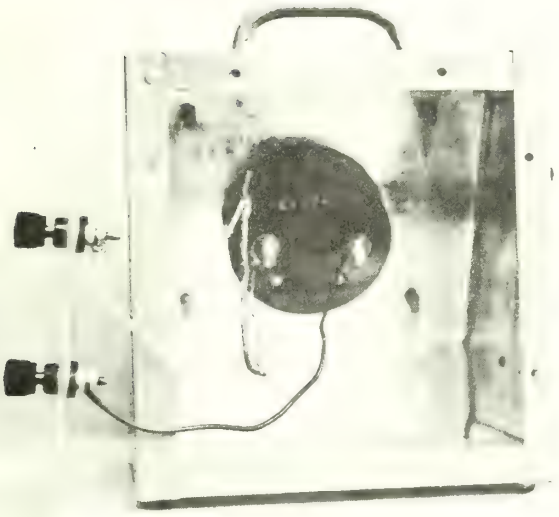


Figure 2.--Reference junction wiring

to the meter is called extension wire. Both the thermocouple and extension wire contain two strands of dissimilar metals, one of which is iron and the other constantan and is referred to as iron-constantan wire.

Insulation.--Many kinds of insulating materials are available. Each strand of the iron-constantan wire is insulated. The two insulated strands are then usually overwrapped with additional insulation to form a parallel paired wire. The thermocouple wire insulation must be able to withstand at least 1100-1200° F. and must be protected against abrasion. The insulation for the extension wire must be weatherproof if the wire is exposed to moisture during use.

Gage.--The heavier gage thermocouple wire will last longer than the lighter. The gage used for extension wire is based primarily on cost. The lighter gage costs less provided the type of wire and insulation are the same.

Condition of use.--Thermocouple wire may be used also as an extension wire provided that none of the wire on the exterior of the kiln is exposed to moisture. However, wire classified by manufacturers as extension wire should not be used for thermocouple application.

Recommended thermocouple wire.--The following information should be furnished the manufacturer: iron-constantan parallel paired thermocouple wire, 16 or 18 gage, solid, asbestos insulated, stainless steel mesh overbraid, amount of wire needed. The price of this wire is 28 to 30 cents per foot.

Recommended wire for use as extension.--The following thermocouple wire is recommended for use as extension wire because of the low cost: iron-constantan parallel paired thermocouple (or extension if available) wire, 24 gage, polyvinyl insulation. The price of this wire is approximately $3.00 per 100 feet.

Any iron-constantan wire constructed of any heavier gage (22-16) and of any weatherproof insulation may be used. The cost, however, may be as high as $15.00 to $17.00 per 100 feet.

Wiring of Meter, Maintenance and Use

The reference junction, which measures the air temperature in the vicinity of the meter, is made by taking a short piece of the constantan extension strand and attaching it to the positive or plus terminal of the meter. A short piece of iron strand is then twisted and soldered to this constantan strand as shown in figure 2. A slightly longer piece of constantan strand is attached to the negative or minus terminal of the meter. If there is any doubt as to the identify of the strands, a magnet can be used to identify the iron strand.

Binding posts, clips, or jacks should be attached to the two ends of the above mentioned strands so that the meter can be easily moved from one thermocouple to the next; or for convenience, the extension wires leading to the thermocouples can be passed through a multiple switch. By using the switch arrangement, it will not be necessary to move the meter.

The meter should be handled as a delicate instrument and should be protected from the weather. Preferably, it should be mounted on a panel or in an instrument box similar to the one shown in figure 2. When the meter is disconnected from the thermocouples, the needle should be on the zero line of the meter scale. Needle adjustment can be made by turning the screw head on the face of the meter.

It should be remembered that the meter is calibrated for a reference junction temperature of 75° F., and deviations from this temperature will result in some error. During the hot summer months, the meter should be placed away from the kiln wall so that the heat from the kiln will not increase the temperature of the reference junction more than the air temperature. During winter operation, when extreme cold temperatures can be expected, it may be desirable to increase the reference junction temperature by placing the meter near the kiln. If this is inconvenient to do, the temperature correction should be made.

Thermocouples

Many types of commercial thermocouples are available and may be purchased ready for use. However, the thermocouples can be made by the charcoal kiln operator at small cost. Strip approximately 1 inch of insulation from the end of the thermocouple wire of appropriate length and twist the two strands together. This forms a thermocouple. For best results, the tip of the twisted strands should be welded together as shown in figure 3.

Thermocouple Placement

The kiln can be wired for any number of thermocouples. For a 7-cord kiln or larger, at least five thermocouple locations are recommended. All five thermocouples should be located along the lengthwise centerline and inserted through the roof as shown in figure 4. The front thermocouple should be located 1 foot behind the kindling area, the second at kiln center and the third 2 feet from the rear wall. All three thermocouples project only 6 inches down from the ceiling. Thermocouple 4 is inserted through the same ceiling hole as number 2 but projects halfway down into the kiln. Thermocouple 5 is located by number 3 but projects down into the kiln to within $2\frac{1}{2}$ feet of the floor. Since the thermocouple wire is flexible, it will conform to the wood which is placed around it. During unloading, the two longer thermocouples can be swung out of the way.

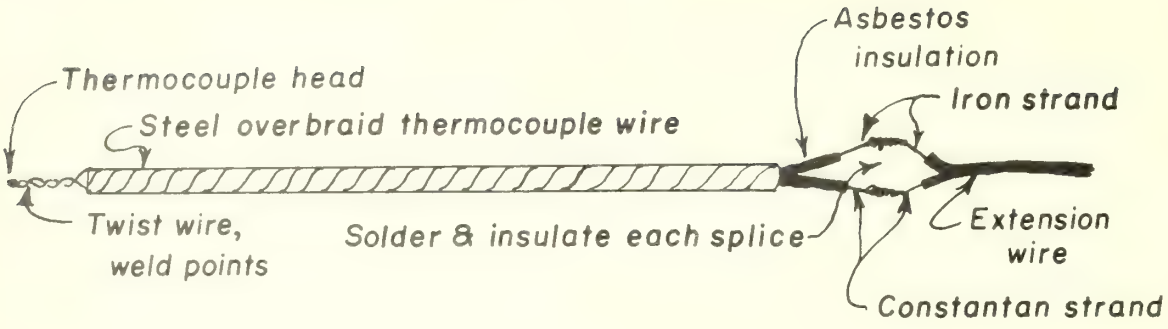


Figure 3.--Thermocouple construction.

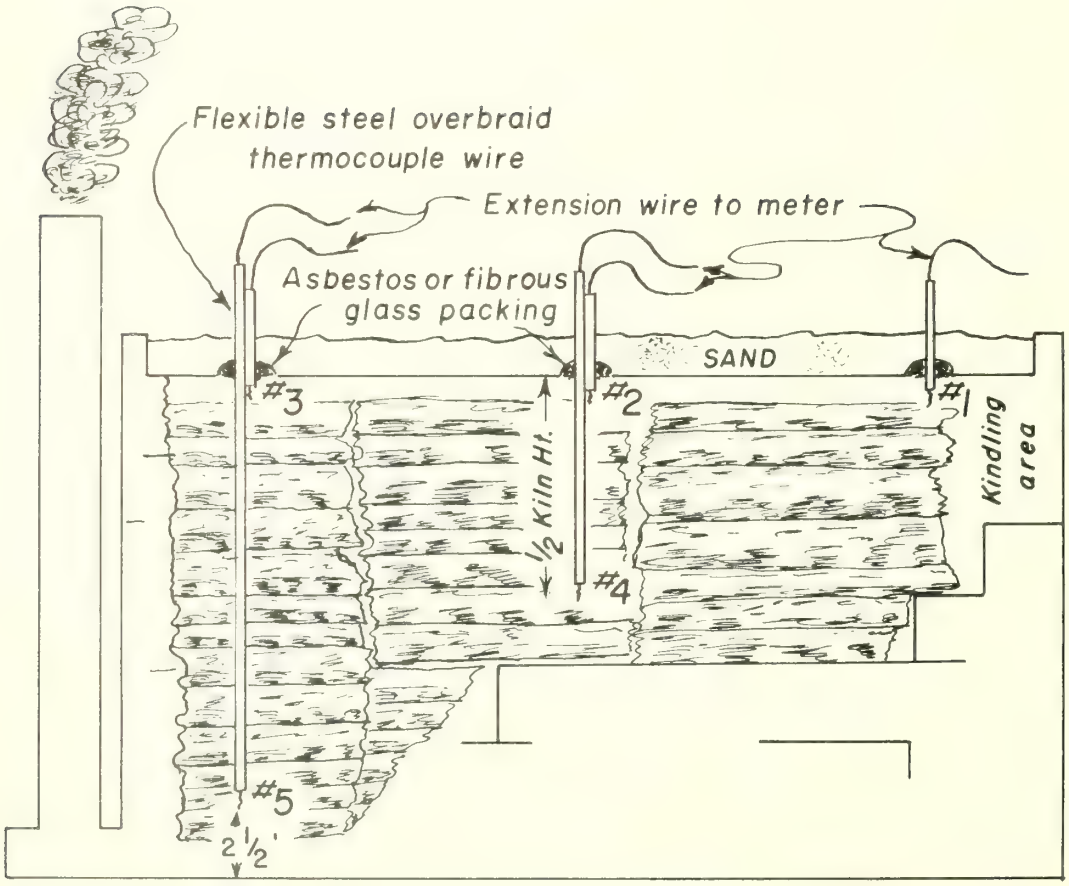


Figure 4.--Thermocouple location.

Optional thermocouples can be suspended from the ceiling near the kiln wall or can be mortared into the wall at various heights during kiln construction in such a manner that the head of the thermocouple projects into the kiln only an inch. These additional thermocouples will enable the operator to keep a closer check on coaling uniformity and on kiln wall temperatures to prevent deterioration due to excessive temperatures of over 950° F.

The thermocouples projecting into the kiln through the ceiling should be wired to the roof support to prevent them from slipping into the kiln. The exterior sections of the thermocouples are connected to the extension wires. Care must be taken that the iron strands of the thermocouple wires are soldered to the iron strands of the extension wires and the constantan strands to the constantan strands. It is also desirable to insulate these connections to prevent accidental shorting of the circuit.

Temperature Pattern and Temperature Control

The temperatures recorded on thermocouple number 1 during the firing operation depend on several factors: amount and condition of kindling, amount of fuel oil added, amount of available oxygen and direction of draft. If conditions are good and the kiln has rear ceiling ports to vent the smoke during the firing phase, temperatures of 1200-1400° F. may be expected. This high temperature should not last longer than 10 to 15 minutes and should be permitted only in kilns with metal ceilings.

Temperature pattern.--After the initial flare-up, the average temperature recorded on thermocouples 1 through 3 is expected to decrease greatly. If temperatures of 500-600° F. have been reached, maintained, and gradually increased over a period of a few hours across the top of the kiln charge, the operator can feel assured that precoaling conditions have been reached. This temperature should be permitted to increase to 900° F. for good coaling condition and should be maintained during most of the burn. During this period, temperatures recorded on thermocouples 4 and 5 are gradually increasing. It is to be expected that the wood in the vicinity of thermocouple 5 will be the last to reach coaling temperature.

As the wood coals, it gradually settles, moving further away from the top three thermocouples. During the latter part of the burn, the average temperature for thermocouples 1 through 3 may decrease slightly. However, the temperatures recorded at thermocouples 4 and 5 should still be increasing.

The end of the coaling period is indicated by the thinning out of the chimney smoke. At this time, it is desirable that thermocouples 4 and 5 record a temperature of at least 825° F., and this temperature should have been maintained for several hours prior to kiln closure.

Temperature control.--The temperature control method is a simple procedure of increasing the air intake if the temperature is too low, or decreasing the air intake if too high.

To maintain accurate temperature measurement conditions, the thermocouples should be replaced occasionally because of a gradual decrease in accuracy through use. A break or a short circuit in the wire may be indicated by no meter response or by the meter needle swinging past the high scale mark. If the kiln is to be inoperative for an extended period of time, it is advisable to coat all the exposed iron strands of the wiring system with a light oil to prevent corrosion.

Partial List of Suppliers*

Microameter - Price approximately $20.00

Allied Radio 100 N. Western Ave. Chicago 80, Illinois	Catalog No. 160 Stock No. 67F444 D. C. Microameter, Range 0-25 2200 ohms internal resistance
Burstein-Applebee Company 1012-14 McGee Street Kansas City, Missouri	Catalog No. 571 Stock No. 29A1338 D. C. Microameter, Range 0-25 2200 ohms internal resistance
Newark Electric Company 223 W. Madison Street Chicago 6, Illinois	D. C. Microameter, Model 29, No. 55F175, Range 0-25, 2200 ohms internal resistance

Thermocouple, thermocouple wire and extension wire

Most of the companies have state or regional representatives which cannot be listed here. The home office addresses are:

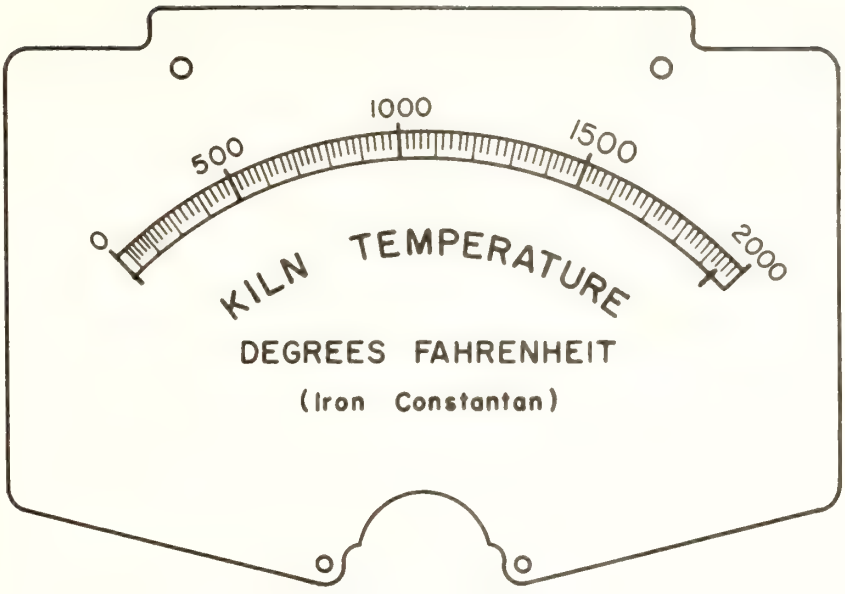
The Bristol Company
Waterbury 91, Connecticut

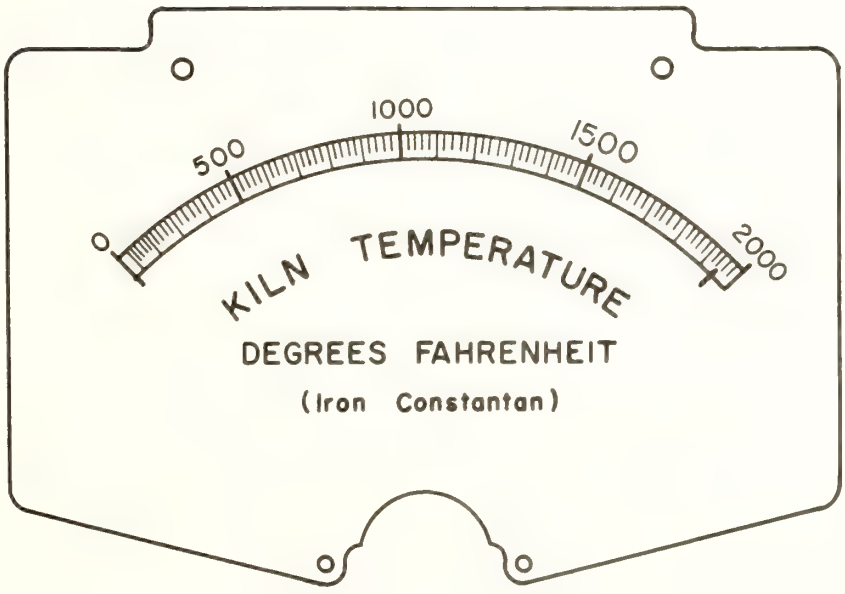
The Lewis Engineering Company
Naugatuck, Connecticut

Thermo Electric Company, Inc.
Saddle River Township
Rochelle Park Post Office, N. J.

Minneapolis-Honeywell Regulator Company
Wayne and Windrim Avenue
Philadelphia 44, Pa.

* The inclusion or exclusion of names in this list does not imply endorsement or lack of endorsement of any company or products by the Forest Service.





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BUYING PULPWOOD BY WEIGHT

As Compared with Volume Measure

by Michael A. Taras

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

U. S. DEPARTMENT OF AGRICULTURE · FOREST SERVICE

BUYING PULPWOOD BY WEIGHT:

As Compared with Volume Measure

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Michael A. Taras
Forest Utilization Service
Southeastern Forest Experiment Station

Introduction

During the past few years several pulp and paper companies in the Southeast have started to purchase pulpwood by weight rather than by volume. The trend toward buying by weight is strong and getting stronger.

This conversion from volume to weight measurement of pulpwood brings up many questions. For instance, is the weight basis fair to both buyer and seller? What are exact weight equivalents for a cord of wood? So far, the weight basis seems to be working out with reasonable justice to buyer and seller. With regard to equivalents, we do not have exact answers because the matter is complicated by differences in species, age, season, region, time since cutting, diameter of average stick, length of average stick, height of tree, rate of growth, whether bark is attached or removed, etc. Some valuable work has been done on equivalents; this paper is a gathering-together of such work to help clarify the subject.

Measuring Wood by Volume

Problems of volume measurements of stacked wood were studied in Germany as early as 1765; between 1879 and 1881 some reliable figures were published on the wood content of a cord (10).

The cord method of measurement was adopted and used in this country because it was simple and convenient, being easy to apply anywhere, especially in the forest, and not because of its accuracy, as can be easily pointed out. For lack of a better method, the cord has been used for over a half century without too much apparent suffering by either the producer or supplier.

Today, the most generally accepted definition of a standard cord is a stack of wood whose gross volume equals 128 cu.ft. In Canada, cord dimensions of 4 ft. x $4\frac{1}{4}$ ft. x 8 ft., which equal 144 cu.ft., have been used. In various parts of the United States, stack dimensions of 4 ft.x 5 ft.x 8 ft., having a stacked volume of 160 feet and known as a "unit" have been used and still are in use. Thus, it is still necessary to specify the gross volume when speaking in terms of cords. In an effort to standardize, some states have passed laws expressing a specific stacked gross volume of 128 cu.ft. as the standard cord.

Studies as early as 1881 showed that the solid wood content of a cord varied from 51 to 92 cu. ft. (10). More recent work shows a range of 64.0 to 102.4 cu.ft. Chapman and Meyers (8) report that for straight wood 8 inches in diameter and larger, the greatest actual solid content per cord of piled wood is about 105 cu.ft., or 82 percent of 128 cu.ft. of combined air space and wood. The solid wood content can drop to 65 cu.ft. for wood 3 inches in diameter, and as low as 50 cu.ft. for 1- and 2-inch sticks.

The influence of stick length on the variability of solid wood volume in a cord is shown in figure 1 (15), and the effect of stick quality (crook) on volume variability is illustrated in figure 2 (10).

Some species are cylindrical or tapering, thick or thin barked, rough or smooth barked, or characteristically knotty, and all of these factors influence the volume per cord. In recent Forest Service studies covering the entire South, an average cord of pine was assumed to have 72 cu.ft. of solid wood per cord, and hardwoods 79 cu.ft. (7).[1/]

MacKinney and Chaiken (12) in a study on loblolly pine in the Mid-Atlantic Coastal Region found an average cord contained about 78 cu. ft. of solid wood; figure 3 shows the variability in solid wood volume of a cord with different average bolt diameters.

In addition to these measurable variables, differences occur with the scaler; his methods, mental attitude, and application of correction factors for cull often have an influence on measurement.

Measuring Wood by Weight

Measuring and purchasing wood by weight is by no means new, but it was only in recent years that sufficient interest was stimulated in the system and attempts were made to introduce it as a method of purchasing pulpwood. Weight purchases in the past were almost impossible because the purchase was usually made in the woods and because of the weight differences.

It is no longer inconvenient to apply this method, since most wood is now scaled at the mill or concentration yard and not in the forest. However, the other reasons for questioning the system still exist. A limited number of studies have been made on cord volume and weight relationships, but no uniform conversion factors have been developed.

Schumacher (14) in 1946 worked out factors to convert the weight of green wood with bark to cords. This study disclosed that the volume-weight ratio for pulpwood varied significantly from one area to another, and a single conversion factor could not be used.

1/ The greater amount of volume in a cord of hardwood is attributable to the larger diameter of average hardwood.

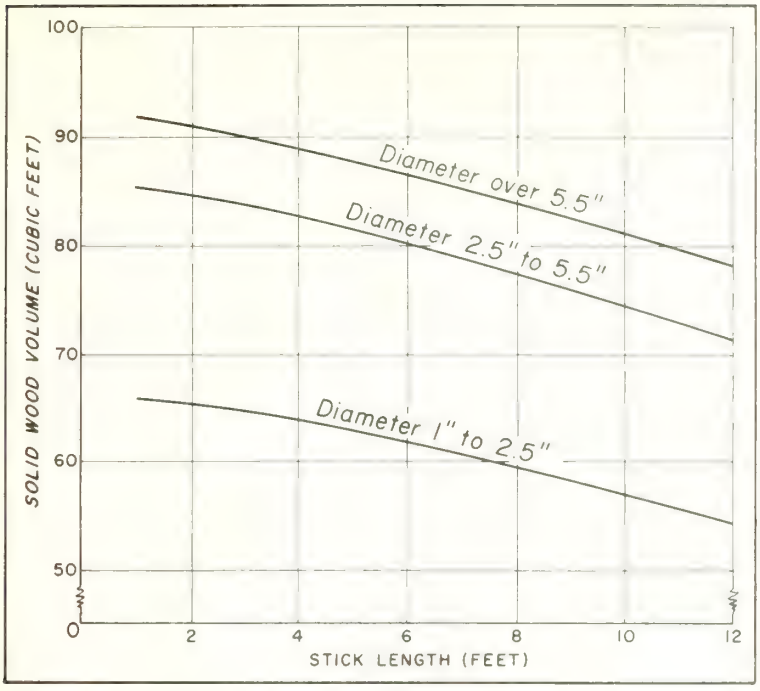

Figure 1.--Influence of length of stick upon solid wood volume of a cord, for conifers (15).

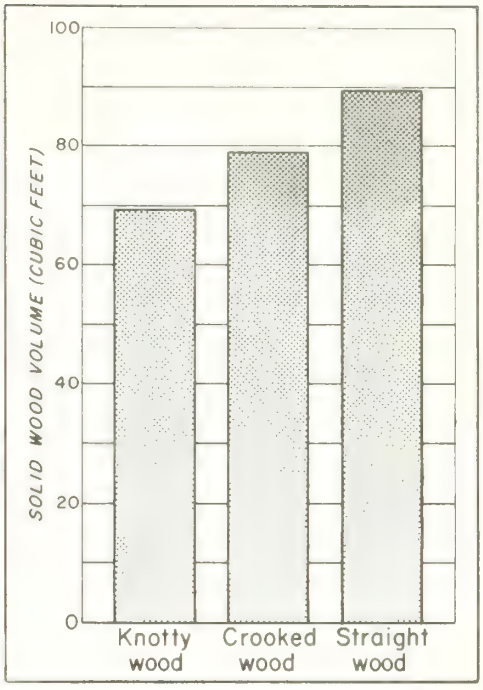

Figure 2.--Influence of stick quality on solid wood volume of 5-foot cordwood (10).

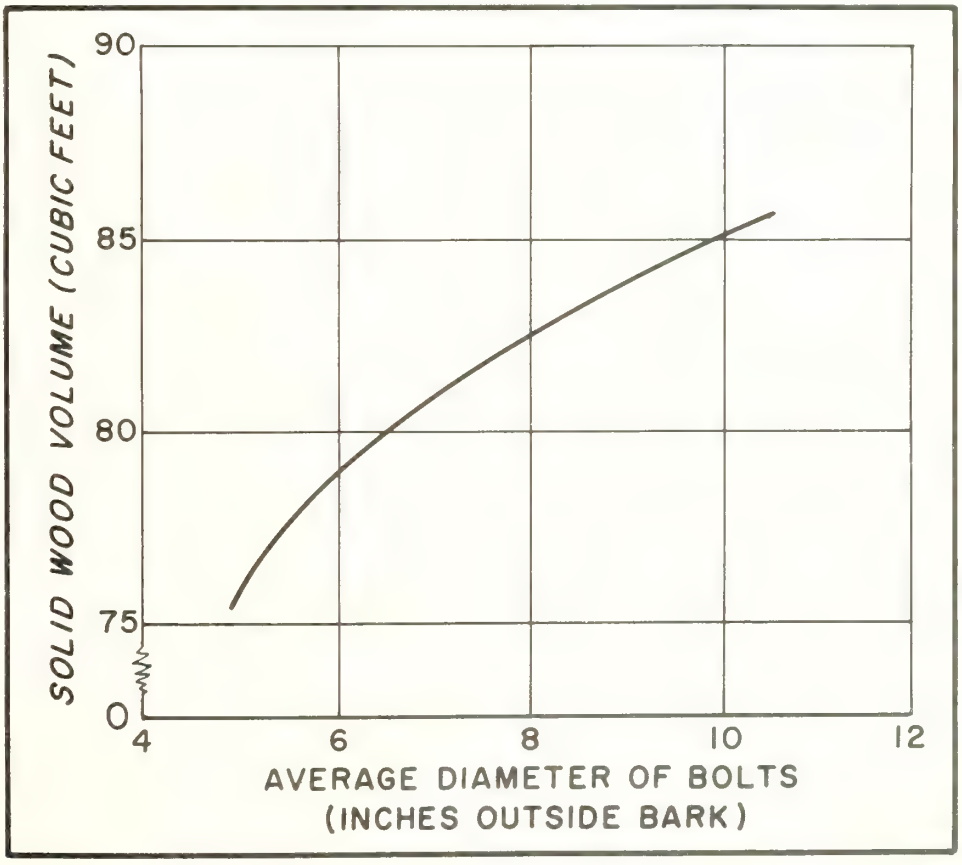

Figure 3.--Influence of average bolt diameter on solid wood volume of stacked cordwood (12).

In 1941, R. H. Miller (13) of the Forest Products Laboratory made a study on measuring green southern yellow pine pulpwood by weight and by cord. One hundred truckloads of pulpwood were studied. Most of the pulpwood was loblolly pine, with some slash and longleaf. This study showed that a standard cord of green unbarked southern yellow pine weighed an average of 5,603 pounds. Other statistics pertaining to this study are as follows:

Item	Diameter	Weight of bark	Moisture content	Volume of solid wood	Volume per ton of green wood
	Inches	Percent	Percent	Cu.ft.	Cu.ft.
Average	5.3	10.4	54	73.76	26.33
Range	2-14	6.4-23.0	42-65	59.5-86.5	22.5-30.0

A correlation was found between the amount of solid wood per ton, the average diameter, and the number of bolts, as well as between solid volume of wood in a cord, the average diameter of the bolts, and the number of bolts in a cord. However, neither weight measure nor cord measure showed a marked superiority in determining the actual amount of solid wood in a cord.

The Forest Products Laboratory (1, 4, 5, 6, 9) over a period of 30 years has accumulated some data on cord volumes and weights of various species in the United States. Some of the cord weights of the various species growing in the Southeast and worked on at the Laboratory are shown in table 1.

The weight values in the following table show the variability that exists between species, as well as within species. The factors influencing these variations in weight are as follows:

1. Volume--the amount of wood in a cord, as pointed out previously, is affected by stick diameter, length, bark thickness, and quality.

2. Density--volume for volume, wood density varies between species, as well as within a species. It is readily affected by percent of summerwood, rate of growth, and position in the tree.

3. Moisture content--the moisture content of wood varies between species and within species between heartwood and sapwood.

Current Weights Developed

Several pulp companies have approached the problem of determining the weight equivalents from a scientific standpoint and are studying the influence of the various factors causing weight variation. Others have actually

weighed and scaled thousands of cords of wood and have developed an average weight for a cord. The weight equivalents being used today vary by species, pulp mills, and localities or points of origin. Figure 4 shows the variation between weights per cord being used by various pulp companies throughout the Southeast. The average weight for pine is 5,232 pounds and hardwood 5,758 pounds. The rather large variations may be justified because of the weight variables in different species and different sections of the South.

Table 1 — Weights of Cordwood Determined in Pulping Experiments at the U. S. Forest Products Laboratory

Species	Weight Unbarked (Lbs.)	Weight Barked (Lbs.)	Calculated Oven Dry Wt. (Lbs.)	Solid Wood Vol. (Cu. Ft.)	Moisture Content[1] (Percent)	Spec. Grav.[2]
Longleaf pine						
Rapid growth (butts)	6245	5615	2908	78.4	93.1	.55
Medium growth (butts)	6374	5714	2920	82.3	95.7	.56
Medium growth (tops)	5967	5236	2418	81.5	116.5	.49
Slow growth (butts)	6152	5310	2895	76.2	83.4	.59
Shortleaf pine						
Rapid growth..	5713	4903	1916	73.9	155.8	.41
Medium growth..	5669	4994	2037	77.4	145.1	.42
Slow growth	5763	5207	2478	85.5	110.1	.46
Slash pine						
Rapid growth	5504	4490	....	66.2	....	.45
Rapid growth (no heartwood)	5271	4333	....	67.7	....	.43
Medium growth	5759	5011	....	72.9	....	.52
Medium growth (contains heartwood)	5577	4763	....	75.8	....	.51
Slow growth	5794	4906	....	72.2	....	.54
Loblolly pine						
Straight, clear	5500	4920	....	80.2	....	.52
Slightly crooked & knotty	5750	5280	....	82.0	....	.49
Markedly crooked & knotty	5390	4950	....	75.9	....	.45
Sand pine	5083	4517	2386	84.4	89.3	.46
Sand pine	4520	4186	2713	90.8	54.3	.46
Cypress (stunted)	4587	3915	....	71.8	....	.46
Swamp blackgum	5724	5096	3088	78.1	65.0	.55
Swamp blackgum	5677	4900	....	76.2	....	.52
Sweetgum	5670	4880	....	....	....	....
Sugarberry	5540	4890	....	....	....	....
Blackjack oak	5760	4700	....	....	....	....
Green ash	4930	4320	....	....	....	....

[1] Based on oven-dry weight

[2] Based on oven-dry weight and volume green

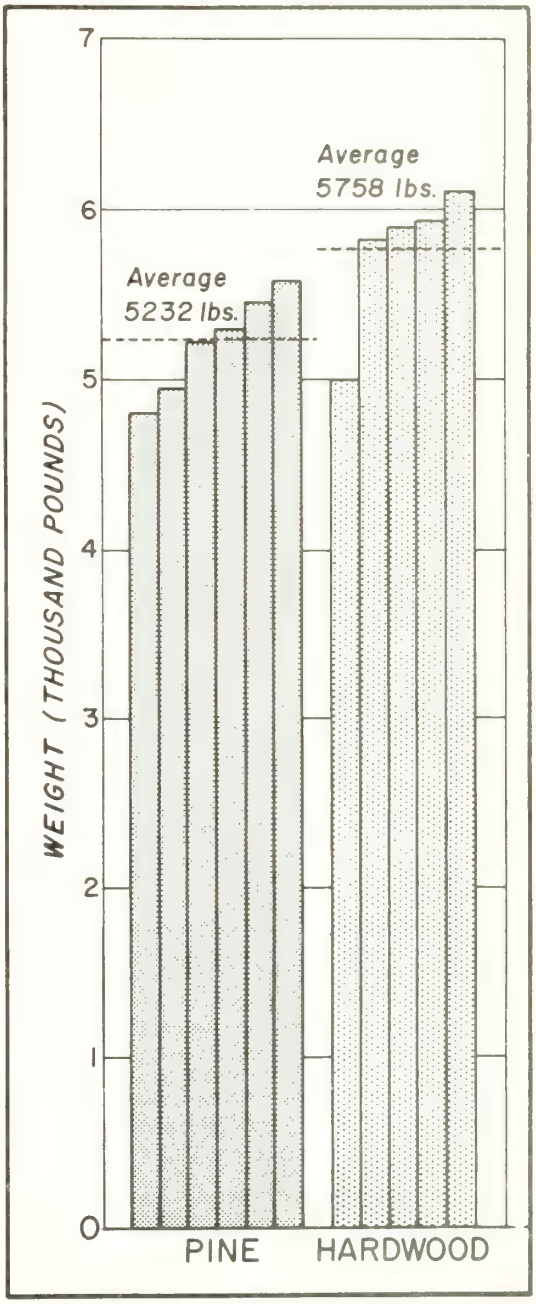

Figure 4.--Weights per cord currently being used by pulp companies in the Southeast.

Calculating the Weight of Wood

The weight per cubic foot of any wood can be readily calculated if we know its specific gravity (based on oven-dry weight and green volume) and moisture content. Weight values have been worked out by the Forest Products Laboratory and are published in Technical Note No. 218 (2) and the Wood Handbook (3). The weight per cubic foot of wood at any moisture content can be calculated by the formula:

$$\text{Density} = \text{specific gravity} \times 62.4 \left(1 + \frac{\text{percentage moisture content}}{100}\right)$$

In order to use this formula, it is necessary to have an accurate determination of both specific gravity and moisture content of the wood being measured.

Table 2 compares calculated weights and actual weights of the solid wood content of several cords of longleaf pine, shortleaf pine, sand pine, and swamp blackgum. Actual weights were determined by weighing and are taken from table 1. Calculated weights were determined by the above formula, using the moisture content, specific gravity, and volume listed in table 1.

These data show that in some cases, as in shortleaf pine, the difference between actual weight and calculated weight is very small and does not vary greatly. However, in the case of longleaf pine, sand pine, and swamp blackgum, some of the values vary considerably. These large differences could be due to inaccuracies in measuring the moisture content and specific gravity of the wood.

Small variations from the true specific gravity or moisture content can mean considerable changes in weight. For each drop or gain in specific gravity of .02 at the 100-percent-moisture-content level, the weight of wood will change about 2.5 pounds per cubic foot. A difference in moisture content of 5 percent around the 100-percent-moisture-content level will cause a change of from 1 to 2 pounds per cubic foot. In a cord containing 72 cubic feet of solid wood, a variation of .02 from the true specific gravity at 100 percent moisture content would mean a loss or gain of 180 pounds per cord. In the case of swamp blackgum, the presence of heartwood and variation in moisture content between heartwood and sapwood are also influencing factors.

The determinations in table 2 were based on solid wood volume alone in order to show applicability of the formula and did not include bark, which is another variable to consider. Some studies have shown that the bark averages about 10 percent of the total weight of the cord and may vary from 8 to 20 percent. Little information is available at present on bark weight and its influence on cord weight.

The question may be asked, "Why can't average values be used to determine cordwood weights?" Average values for specific gravity and moisture content may possibly be suitable if the results are within limits of acceptable error. Calculated weights based on average values of specific gravity and moisture content are only approximations because of variability in specific

gravity and moisture content. It is known that the specific gravity of a species may vary from region to region because of site quality. If average values are suitable, the regional effect should be taken into consideration and average values computed for different regions. Suitable information on average moisture content between species, as well as within species, is lacking. There is also limited information on storage time and its effect on weight. Lindgren (11), in a pulpwood storage study, shows very little loss in moisture content for slash pine cut in July and seasoned for 2 months.

A comparison of actual weights and calculated weights based on average moisture content and average specific gravity of several species is shown in table 3. The actual weights were determined by weighing and were obtained from table 1. The calculated weights are based on the average specific gravity and average moisture content listed for the species by the Forest Products Laboratory (2).

In table 3, the calculated weights determined from average values in general are lower than the actual weight, indicating that either the average specific gravity or average moisture content, or both, are not truly representative of the cords measured.

In considering average values only, that is, for specific gravity and moisture content, assuming a standard cord to contain an average of 72 cu.ft. of solid wood, we would develop weights as shown in table 4.

Table 2 — Comparison of Actual and Calculated Weights of Cordwood

Species	Actual Weight of Barked Wood (Pounds)	Solid Wood Volume (Cu. Ft.)	Calculated[1] Weight of Barked Wood (Pounds)	Difference from Actual Weight Pounds
Longleaf pine				
Rapid growth (butts)	5615	78.4	5190	— 425
Medium growth (butts)	5714	82.3	5629	— 85
Medium growth (tops)	5236	81.5	5387	+ 151
Slow growth (butts)	5310	76.2	5128	— 182
Shortleaf pine				
Rapid growth	4903	73.9	4840	— 63
Medium growth	4994	77.4	4961	— 33
Slow growth	5207	85.5	5147	— 60
Sand pine	4517	84.4	4574	+ 57
Sand pine	4186	90.8	4013	— 173
Swamp blackgum	5096	78.1	4420	— 676

[1] Weight based on volume, moisture content, and specific gravity listed in Table 1

Table 3 — Comparison of Actual and Calculated Weights of Cordwood Based on Average Moisture Content and Average Specific Gravity Values

Species	Actual Weight of Barked Wood (Pounds)	Solid Wood Volume (Cu. Ft.)	Calculated[1] Weight of Barked Wood (Pounds)	Difference from Actual Weight (Pounds)
Longleaf pine				
Rapid growth (butts)	5615	78.4	5417	— 198
Medium growth (butts)	5714	82.3	5687	— 27
Medium growth (tops)	5236	81.5	5632	+ 396
Slow growth (butts)	5310	76.2	5265	— 45
Shortleaf pine				
Rapid growth	4903	73.9	4663	— 240
Medium growth	4994	77.4	4884	— 110
Slow growth	5207	85.5	5395	+ 188
Loblolly pine				
Straight, clear	4920	80.2	4836	— 84
Slightly crooked & knotty	5280	82.0	4945	— 335
Markedly crooked & knotty	4950	75.9	4576	— 374

[1] Weight based on average moisture content values and average specific gravity values of the respective species as listed by the Forest Products Laboratory.

Table 4 — Weights for the Various Pine Species in the Southeast

Species	Specific Gravity	Moisture Content (Percent,	Density (Lbs. Cu. Ft.)	Vol. Per Cord (Cu. Ft.)	Calculated Wt. Without Bark Lbs.,	Estimated Wt of Bark (Lbs.)	Calculated Wt with Bark (Lbs.)
Loblolly pine	0.46	110	60.3	72	4557	700	5257
Longleaf pine	0.53	105	67.8	72	4881	650	5331
Shortleaf pine	0.44	120	60.4	72	4349	500	4849
Slash pine	0.52	120	71.4	72	5140	500	5640

A comparison of the calculated hypothetical values listed above and those that are being used by the pulp industry today can be seen in figure 5. The calculated values fall in the same range of values being used by the pulp companies, from 4,800 to 5,600 pounds. Though the species are not noted in the data obtained from the pulp companies, the areas from which they come and their weights are indicative of what they might be. The heavier groups (5,450, 5,583) are probably longleaf and/or slash pine. The others are probably shortleaf and loblolly pine.

The current practice in purchasing pulpwood by weight is to pay for it on a hundredweight basis. Current prices are about 27 to 31 cents per hundred pounds. If a cord of wood weighs 4,800 pounds, it will bring a price of $13.44. A cord weighing 5,583 pounds will bring $15.48. For an individual to lose a dollar on a cord of wood, the values being used by the pulp companies would have to be approximately 400 pounds below the average.

Summary and Conclusions

From the data presented, it has been shown that measuring wood by the cord or volume method can be unfair to either buyer or seller because cord volume is influenced by stick diameter, length, quality, and other factors.

It has also been shown that the weight of a cord of wood varies considerably because of the variations that exist in wood density and moisture content.

Since wood is a heteregenous material, it is not possible to develop one single factor that will serve all existing variables and can be used for wood in general.

Weight scaling is now being considered favorably for several reasons:

1. Positive records of a transaction can be made without human judgment entering the picture.

2. The method is quick, requiring no special handling, and saves time for both the buyer and seller.

3. It provides an incentive for better piling of wood on trucks and thus increases volume handled by the supplier.

4. A greater volume of wood can be handled in less time and with less personnel.

5. It encourages prompt delivery of green wood to the mill, which is desirable from the standpoint of pulping.

6. Inventories are more easily maintained.

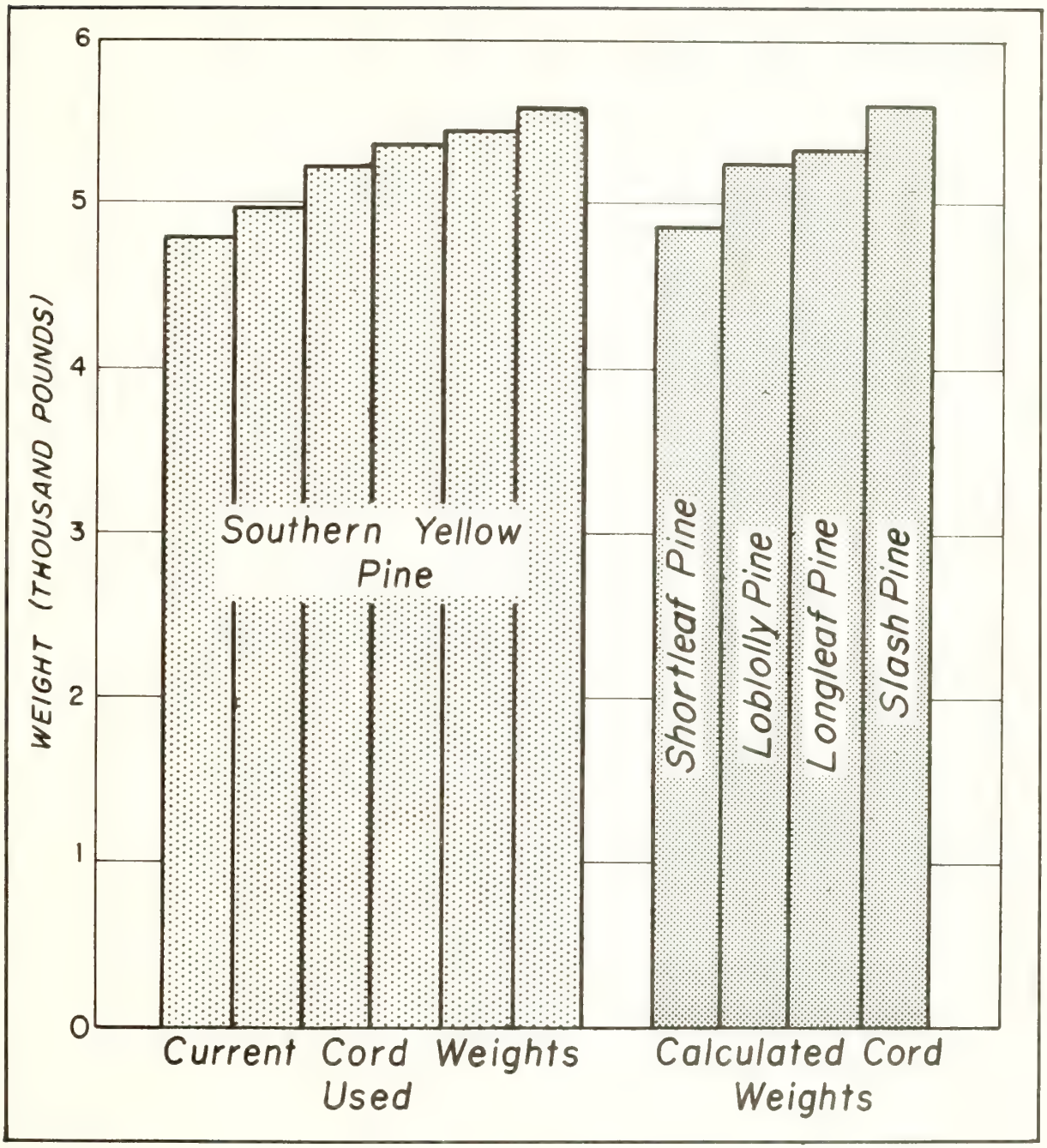

Figure 5.--A comparison of cord weights used by pulp companies, and calculated weights based on average specific gravity, average moisture content, and a cord volume of 72 cu. ft.

There appears to be no real necessity for developing conversion factors to convert cord measure to weight or vice versa since the weight measure can stand on its own, as it has for many other agricultural commodities.

Forestry cruise data are easily converted into cubic feet and can be transposed to weight figures with average data now available. Much more accurate measurements of weight of wood in standing trees can be obtained if field measurements are made of specific gravity and moisture content. Research is now under way on methods of determining specific gravity in the field.

There is an opportunity for a great deal more research in measuring and handling wood and wood residue by weight. It is hoped that government, state, and industry will continue such research with a free interchange of information so that the public can be fully informed.

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Common Browse Plants of the Georgia Coastal Plain

Their chemical composition and contribution to cattle diet

by

L. K. Halls, F. E. Knox

and V. A. Lazar

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

Joseph F. Pechanec,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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COMMON BROWSE PLANTS OF THE GEORGIA COASTAL PLAIN:

Their Chemical Composition and Contribution to Cattle Diet

by

L. K. Halls, F. E. Knox, and V. A. Lazar [1/]

INTRODUCTION

The purpose of this paper is to consolidate available information on several important browse plants of the Georgia coastal plain so that their value and over-all contribution to cattle feed can be more fully assessed and compared to other kinds of forage. Numerous observations and notes pertaining to cattle diet were accumulated in the vicinity of the Alapaha Experimental Range, Berrien County, Georgia, from 1942 to 1955. These provided good estimations as to the kind and amounts of browse plants eaten at various times of the year. An indication of the nutritive value of many individual plants was obtained by means of chemical analyses made during these same years. Although chemical analysis is not a specific measure of digestible nutrients, such data signify the approximate food value of a plant.

Browse plants serve a valuable function for cattle grazing in pine forests of the Georgia coastal plain. Not only does browse contribute to the over-all feed supply but it also commonly enhances the nutritional intake of cattle. Certain species are often high in a particular plant nutrient or mineral that may be deficient or marginal in other kinds of forage. Too, chemical content of browse generally shows less seasonal fluctuation and crude protein does not decrease during dry periods or during the winter as much as in grasses.

In addition, browse adds variety to cattle diet. Livestock prefer a variety of feed rather than a single species. When permitted to move freely among range types, grazing cattle show a great deal of selectivity and frequently shift from one group of plants to another. This may be prompted by variation in chemical composition, differences in plant taste or smell, or just a natural desire for change.

1/ Respectively: Range Conservationist, U. S. Forest Service; Chemist, Agricultural Research Service; and Soil Scientist, U. S. Plant, Soil, and Nutrition Laboratory, Agricultural Research Service. This was a cooperative study between the University of Georgia Coastal Plain Experiment Station, the Forest Service, and the Agricultural Research Service. Both the latter are under the U. S. Department of Agriculture.

THE EXPERIMENTAL RANGE

The Alapaha Experimental Range comprises approximately 2800 acres in a forested section of the lower coastal plain of Georgia. Several recognized forest cover types (14) include longleaf-slash pine, slash pine, slash pine-blackgum, and pond cypress. These types intergrade from longleaf pine (Pinus palustris Mill.)[2/] on the relatively high, drier ridges to moist areas around swamps and ponds, where slash pine (Pinus elliottii Engelm.) becomes dominant. Still wetter are the shallow ponds and swamps, where pond cypress (Taxodium distichum var. nutans [Ait.] Sweet) predominates. Approximately two-thirds of the area is occupied by longleaf-slash pine and slash pine types and the other third by slash pine-blackgum and pond cypress.

The two most common soils in the longleaf-slash pine and slash pine types are Lynchburg loamy fine sand and Plummer sand. Soils in low moist areas are Rains, Rutledge, and mixed alluvium.

Shrubs constitute about 23 percent of the total understory vegetation beneath the longleaf-slash and slash pine types of the experimental area (fig. 1). Within the slash pine-blackgum and pond cypress types the overhead cover varied from a fairly open condition to a many-layered, dense thicket of shrubs, hardwood trees, and vines.

2/ Common names taken from reference 7 and scientific names from 8 and 9.

Figure 1.--Sawpalmetto and gallberry are the most prevalent shrubs beneath longleaf and slash pine trees. These and other shrubs constitute about 23 percent of the understory vegetation.

BROWSE COLLECTIONS AND ANALYSES

The proportionate amount that browse plants contributed to total cattle diet was estimated in numerous studies from 1943 to 1952. Frequently during these years, samples of browse were gathered and analyzed for crude protein, calcium, and phosphorus. In 1953 and 1954, a concerted effort was made to further determine the extent that each browse plant was eaten by cattle and to collect samples for chemical analyses during the time of year when the plants were being eaten. When possible, sampling was replicated in two separate ranges.

Collection of browse samples was accomplished while observing the grazing habits of gentle cow herds at various seasons of the year. These cattle moved freely over 300- to 400-acre ranges which supported the cover types previously described. Close scrutiny of the grazing cattle made it possible to ascertain the plant parts and relative amount of particular species eaten. These same portions were then collected from similar plants closeby. Care was exercised to collect the proper ratio of leaves, stems, and shoots. Because diet samples were gathered wherever cows grazed, each sample was a composite of several plants of the same species from different sections of the range area.

Analyses for crude protein, ether extract, ash, calcium, and phosphorus were in accordance with procedures of the Association of Official Agricultural Chemists (2), and cellulose according to Crampton and Maynard (4). Lignin content was determined in accordance with the methods of Davis and Miller (5).

Portions of most plants collected in 1953 and 1954 were further analyzed for the minor elements, copper, iron, manganese, zinc, and cobalt by methods of Parks, et al. (13) and Gregory, et al. (6).

A comparison of the nutrient content of browse with that of a composite cattle diet sample consisting of grasses, broadleaved herbs, and browse was made possible through the availability of data obtained in concurrent but separate studies on the same ranges. 3/

DESCRIPTION OF BROWSE PLANTS

Browse consists of twigs, shoots, and leaves of shrubs, trees, or woody vines available for grazing by livestock or game. Growth of this kind is abundant and prolific in the coastal plain. Fourteen such plants are described herein. Each contributed 1 percent or more of the total cattle diet during some portion of the year (table 1). Pertinent information concerning browse growth habits, occurrence, and season when ordinarily grazed is included below.

3/ Halls, L. K., Hale, O. M., and Knox, F. E. Digestibility and nutrient content of wiregrass forage. 1956. (Manuscript in process of publication.)

Table 1.--Contribution of browse plants to cattle diet at various seasons of the year
(in percent)

Species	Ratio of total forage intake			
	Spring	Summer	Fall	Winter
Red maple	(1/)	1	--	--
Red chokeberry	1	(1/)	--	--
Summersweet clethra	2	(1/)	--	--
Buckwheattree	(1/)	1	1	1
American cyrilla	1	(1/)	(1/)	2
Bedstraw St. Johnswort	2	--	--	1
Gallberry	1	(1/)	--	--
Myrtle dahoon	1	(1/)	1	4
Sweetbay magnolia	1	(1/)	(1/)	3
Blackgum	2	2	1	--
Running oak	(1/)	(1/)	(1/)	--
Sawpalmetto	3	3	1	3
Laurel greenbriar	1	(1/)	--	2
Staggerbush	1	1	(1/)	--
Total	16	8	4	16

1/ Less than 0.5 percent.

Red maple (Acer rubrum L.) is a deciduous tree 80 to 90 feet tall that borders streams, swamps, and upland forests within the slash pine and slash pine-blackgum type. The leaves of small young trees and sprouts at the base of trees are grazed occasionally during the spring and summer.

Red chokeberry (Aronia arbutifolia [L.] Ell.) is commonly found in low moist pine lands and thickets bordering swamps and branches. Cattle graze the young leaves and twigs of this medium sized (3 to 10 feet tall) deciduous shrub sparingly in the spring and summer.

Summersweet clethra, or sweet pepperbush (Clethra alnifolia L.), a deciduous shrub, 3 to 10 feet tall, is also found in moist pinelands, thickets bordering swamps and bays, and at the outer edge of swamps. Leaves and young shoot growth are grazed by cattle during the spring.

Buckwheattree (Cliftonia monophylla [Lam.] Sarg.), locally known as titi, is a large shrub or tree 25 to 30 feet tall, with evergreen leaves. This plant typically forms dense thickets along the borders of swamps and drainageways and is one of the most prevalent hardwoods in the slash pine-blackgum and pond cypress types (fig. 2). The leaves and twigs of this plant are grazed some during the summer, and also during fall and winter when other green forage is scarce.

Figure 2.--Buckwheattree and American cyrilla form dense, treelike thickets on borders of swamps and drainageways.

American cyrilla, or ironwood, (Cyrilla racemiflora L.) is associated very closely with buckwheattree. The late-falling leaves give this plant a semi-evergreen appearance. Cattle graze new growth of leaves and twigs in the early spring and consume leaves sparingly through the summer and early fall. Amounts grazed increase during late fall and early winter before the leaves are shed.

Bedstraw St. Johnswort (Hypericum galioides Lam.), an evergreen shrub 2 to 6 feet tall, is commonly found within shallow ponds and wet areas of the pond cypress type and also in low, moist areas adjacent to swamps. The evergreen leaves are grazed during late winter and very early spring.

Inkberry, or gallberry, (Ilex glabra [L.] Gray) occurs extensively in the pinelands and low moist areas and swamps of the coastal plain. This very common evergreen shrub, 1 to 10 feet tall, is very objectionable, as it increases the fire hazard of the forest and reduces growth of herbaceous vegetation. The plant is considered to be unpalatable and of very little use to cattle, but young leaves and sprouts that emerge following a winter fire are grazed very lightly during the spring.

Myrtle dahoon (Ilex myrtifolia Walt.) has a considerable range in height, often varying from 5 to 25 feet tall. This shrub or small tree is present in nearly all cypress ponds and swamps of the coastal plain. Cattle graze its leaves and twigs more than any other browse species during the winter in the vicinity of the experimental range (fig. 3). On occasion, this member of the holly family is grazed heavily. Cattle have been observed to search out and feed upon this plant for several hours during the day. They may then go several days without grazing it at all.

Figure 3.--During the winter, cattle graze the green leaves of myrtle dahoon more than any other browse.

Sweetbay magnolia (Magnolia virginiana L.), a large evergreen shrub or tree 20 to 30 feet tall, occurs widely in the bayheads, swamps, and drainageways of the slash pine and slash pine-blackgum types. Sometimes it forms nearly pure stands. The leaves are grazed considerably during the winter. Young, tender twig and leaf growth is also eaten during spring and early summer.

Blackgum, or black tupelo, (Nyssa sylvatica Marsh.) reaches its greatest importance and is a codominant in the slash pine-blackgum type. This large deciduous tree often attains a height of 50 feet or more. It is found growing on imperfectly drained soils bordering swamps and in swamps where the base of the tree is often inundated for extensive periods in shallow water. After a fire, numerous young shoots emerging from the tree base are quite palatable and are readily eaten by cattle (fig. 4). Leaves and twigs from young trees are eaten consistently by cattle through the spring and summer.

Figure 4.--This young clump of blackgum was burned the previous winter. The following spring, cattle readily ate the young shoots and leaves.

Running oak (Quercus pumila Walt.) frequently forms small sparse thickets in the dry well-drained soils of the longleaf-slash pine forest. Very small amounts of the leaves and twigs of this small (1 to 3 feet tall) evergreen shrub are eaten during the spring, summer, and fall.

Sawpalmetto (Serenoa repens [Bart.] Small) assumes several growth habits. The robust stems of this small to large evergreen shrub may be erect or often creeping and rooting. Occasionally they have a subterranean habit of growth. Plants often group together to form small to very large colonies on a wide variety of sites ranging from excessively drained sandy ridges to poorly drained swamps. In the vicinity of Alapaha, Georgia, this species is eaten more consistently through the year than any other browse. During the spring and summer, cattle exert considerable energy to tug at and pull out the young center leaves from the stem base (fig. 5). Regrowth of the center leaves may be grazed several times during the year. The outer portions of the tough, fibrous, fan leaves are eaten during the fall and winter.

Laurel greenbriar (Smilax laurifolia L.) is a vigorous, high-climbing, evergreen vine with very sharp spines along the main stem. It often forms large entanglements in the swamps and wet woods of the slash pine-blackgum and pond cypress types. Young tendrils are grazed before the spines have become hardened in the early spring. During the winter, when cattle move through the swamps in search of green feed, the leaves are eaten considerably (fig. 6).

Figure 5.--Sawpalmetto is grazed throughout the year. Young center leaves are eaten consistently during spring and summer. In addition, the outer portion of fan leaves are consumed during the winter.

Figure 6.--The leaves of laurel greenbriar furnish feed during the winter and early spring.

Staggerbush (Xolisma fruticosa [Michx.] Nash) is an evergreen shrub 3 to 10 feet tall. Its occurrence is frequent but scattered throughout the fairly well-drained soils of the longleaf-slash pine type. Current growth of stems and leaves is eaten some during spring and early summer and very sparingly during late summer.

CONSUMPTION OF BROWSE BY CATTLE

The study showed that browse plants as a group seldom if ever contributed a major share of the cattle diet. They achieved greatest importance (on a weight basis) during the early spring and winter (table 1). At these seasons they comprised approximately 16 percent of the total cattle feed.

In the spring, most of the browse plants were grazed to some degree, but no single plant contributed more than 3 to 4 percent of the total forage intake. The amount and kind of browse eaten at this time was quite consistent from day to day and for different years. Sawpalmetto, blackgum, summersweet clethra, and bedstraw St. Johnswort contributed most of the browse-type forage at this season. Intake of browse declined as summer approached, although several of the species were grazed rather consistently. Very little browse was eaten during the early fall.

At the onset of near-freezing weather in late fall or early winter, most herbaceous forage becomes dry and unpalatable. Presumably this tended to increase the consumption of browse. Grazing was confined primarily to evergreen browse plants, of which myrtle dahoon, sweetbay magnolia, sawpalmetto, American cyrilla, and laurel greenbriar were most important (fig. 7). Grazing of those plants during the winter tended to be erratic. Cattle apparently acquired a temporary craving for a particular plant and would confine their grazing to one or two shrubs such as myrtle dahoon or sawpalmetto for several hours. These plants often supplied 25 to 30 percent of the cattle feed for that particular day. Conversely, the cattle would go several days without consuming any appreciable quantities of these plants.

CHEMICAL COMPOSITION OF BROWSE PLANTS

Crude Protein

During spring and summer the concentration of crude protein in browse was slightly higher than the average of the total forage intake by cattle (table 2). Since browse plants comprised a considerable portion of the cattle feed at this time, they helped to increase the crude protein level in the cattle diet. Without the help of browse, the crude protein content of the total forage intake would have been less than these data indicate.

Figure 7.--In the winter cattle move through swamps and lowland areas in search of green feed. Browse contributes a relatively large amount of feed during this time.

Table 2.--Chemical composition of browse [1/] as compared to the total forage intake by cattle [2/] (in percent)

Season and kind of sample	Chemical composition					
	Crude protein	Lignin	Ash	Ether extract	Cellulose	Other carbohydrates
Spring:						
Browse	11	21	6	4	17	41
Total forage intake	10	13	8	2	32	35
Summer:						
Browse	10	21	4	4	21	40
Total forage intake	9	13	9	2	32	35
Fall						
Browse	7	26	3	4	25	35
Total forage intake -	8	12	7	2	34	37
Winter						
Browse	8	24	4	6	20	38
Total forage intake	5	16	6	3	30	40

1/ Average chemical composition of all browse plants at the season of year they were eaten by cattle.

2/ A composite sample of all grasses, broadleaved herbs, and browse eaten by cattle. See footnote 3.

On the assumption that crude protein of forage should be 8 percent or greater to meet the requirements for any class of cattle (12), most browse plants supplied adequate amounts of this nutrient during the spring and summer. Species such as summersweet clethra, American cyrilla, blackgum, and running oak contained rather liberal amounts (table 3). Sawpalmetto was an exception. During the spring this plant was definitely deficient in crude protein.

Table 3.--Chemical composition of individual browse plants during the season they were grazed most 1/
(in percent)

Season of collection and species	Chemical composition					
	Crude protein	Lignin	Ash	Ether extract	Cellulose	Other carbohydrates
Spring:						
Red maple	11	18	5	5	16	45
Red chokeberry	10	19	6	3	19	43
Summersweet clethra	13	26	7	2	16	36
American cyrilla	13	19	7	4	14	43
Bedstraw St. Johnswort	10	23	2	9	22	34
Gallberry	11	17	3	3	10	56
Blackgum	13	12	4	3	14	54
Running oak	13	26	4	3	18	36
Sawpalmetto	7	21	5	2	32	33
Staggerbush	10	27	6	7	18	32
Winter:						
Buckwheattree	6	22	2	7	15	48
Myrtle dahoon	8	20	3	7	17	45
Sweetbay magnolia	10	21	7	8	20	34
Laurel greenbriar	9	30	2	3	20	36

1/ An average of two or more composite samples taken from separate ranges.

During the fall, average crude protein of browse declined to a submarginal level of 7 percent. But because such meager quantities of browse were eaten at this time, they had little effect on the protein level of the average forage sample.

Browse maintained a fairly high crude protein level of 8 percent during the winter, whereas the average of the cattle diet dropped to a low of 5 percent. Thus, browse plants play a rather significant role in supplying crude protein for cattle grazing forest range at this season. Sweetbay magnolia, myrtle dahoon, and laurel greenbriar were plants highest in crude protein. The evergreen characteristics of these plants account for the fairly high crude protein content as compared to that in the bleached, dry,. herbaceous forage.

Lignin

Browse was much higher in lignin than the average for composite forage samples (table 2). Lignin in browse ranged from approximately 21 percent during the spring and summer to 26 and 24 percent in the fall and winter as contrasted to the extremes of 12 and 16 percent for total forage intake. Blackgum was lowest (12 percent) and laurel greenbriar highest (30 percent) in this component (table 3). Such a high lignin content detracts considerably from the value of browse species because this constituent is practically indigestible and large amounts tend to decrease the digestibility of other nutrients. If taken into the body in appreciable amounts, it seems doubtful whether plants containing large quantities of lignin could be of much benefit to the animal.

Ash

Ash content of browse was generally less than in composite forage samples. This is attributed to the fact that portions of browse collected for chemical analysis usually were well above the ground. They thus avoided sand and dirt in raindrop splatter, which commonly adheres to herbaceous vegetation.

Ether Extract

Ether extract was fairly high in most of the shrubs and, on the average, was about twice as concentrated as the composite sample of cattle diet. This relatively high amount of ether extract was probably a result of the waxes and resins that form on the outer surface of the leaves of browse. These substances become more concentrated as the plant leaves mature, and thus the amount of ether extract was greater in the winter collections.

Cellulose and Other Carbohydrates

The more digestible portion of the carbohydrate fraction is composed of cellulose and other carbohydrates. These nutrients are the main source of energy for animals. Browse plants were relatively low in these nutrients, particularly as regards cellulose. Differences between browse and other plants were greatest during the fall and winter. Thus, browse plants are undoubtedly poor sources of energy during the time of year when high energy feeds are required for animals.

MINERAL COMPOSITION OF BROWSE PLANTS

Major Elements

Calcium.--Browse serves a very valuable function by furnishing a relatively large amount of calcium. Nearly all browse plants contained more calcium than other components of the forage (table 4) and a greater amount than is required for animal maintenance (12). The only exception was

sawpalmetto, and this plant contained inadequate amounts during the spring. Calcium content of browse plants was lowest in the spring, it increased during the summer, and remained at a fairly constant level through the fall and winter. Red maple, red chokeberry, summersweet clethra, staggerbush, and blackgum were highest in this element (table 5). In winter, animals selected browse species that were slightly lower in calcium than those eaten in the fall.

Table 4.--Major element composition of browse [1/] as compared to the total forage intake by cattle [2/] (in percent)

Season of collection and kind of sample	Major element composition	
	Calcium	Phosphorus
Spring:		
Browse	0.48	0.15
Total forage intake	.18	.13
Summer:		
Browse	.59	.12
Total forage intake	.17	.13
Fall:		
Browse	.60	.08
Total forage intake	.15	.11
Winter:		
Browse	.57	.08
Total forage intake	.17	.06

1/ Average composition of all browse plants at the season of year they were eaten by cattle.

2/ A composite sample of all grasses, broadleaved herbs, and browse eaten by cattle. See footnote 3.

Even though browse contains more than sufficient calcium to meet cattle requirements, these plants do not fully compensate for insufficient quantities in other groups of plants. As a result, the calcium content of the average cattle diet was slightly less than the 0.25 percent recommended for normal growth of a 600 pound steer or heifer (12).

Phosphorus.--Browse possessed greater amounts of phosphorus than other groups of plants during the spring and winter but less during the summer and fall. The average phosphorus content of all browse was on the borderline of or below the 0.15-percent level required for any class of cattle (12). However, specific species such as red maple, American cyrilla, staggerbush, and running oak contained sufficient phosphorus during the spring. Browse plants grazed during the winter, even though higher in phosphorus than other groups of plants, were very low in this mineral.

Table 5.--Mineral composition of individual browse plants during the season they were grazed most 1/

Season of collection and species	Major elements		Minor elements				
	Calcium	Phosphorus	Copper	Iron	Manganese	Zinc	Cobalt
	Percent		Parts per million				
Spring:							
Red maple	0.65	0.17	9.0	--	485	--	0.14
Red chokeberry	.87	.11	5.6	66	84	26	.32
Summersweet clethra	.93	.12	10.6	81	751	47	9.30
American cyrilla	.30	.17	8.1	--	60	--	.09
Bedstraw St. Johnswort	.34	.10	--	--	--	--	--
Gallberry	.38	.15	8.4	--	284	--	.12
Blackgum	.65	.12	7.8	79	366	14	6.90
Running oak	.51	.21	12.0	--	373	--	.29
Sawpalmetto	.09	.13	17.0	23	100	15	.06
Staggerbush	.66	.22	9.0	--	357	--	.12
Winter:							
Buckwheattree	.39	.05	4.0	--	157	--	.06
Myrtle dahoon	.62	.06	6.3	--	254	--	.12
Sweetbay magnolia	.55	.10	5.0	74	168	27	.06
Laurel greenbriar	.44	.07	4.7	--	102	--	.05

1/ An average of two or more composite samples taken from duplicate ranges.

Minor Elements

Copper.--Pasturage containing 7.5 p.p.m. (parts per million) of copper is regarded as being healthy (3). On this basis, it was found that most browse plants contain ample amounts of this element during the spring (table 5). Browse was below recommended levels for copper during the winter but remained above 1 to 4 p.p.m., the point where cases of anemia, emaciation, and diarrhea have responded to copper therapy (12). Sawpalmetto, summersweet clethra, running oak, red maple, and staggerbush were particularly high in this element. Blackgum varied considerably, but most samples contained adequate amounts of copper.

Some important forage grasses, pineland threeawn (Aristida stricta Michx.), curtiss dropseed (Sporobolus curtissii [Vasey] Small ex Scribn.), and toothachegrass (Ctenium aromaticum [Walt.] Wood) were collected concurrently and in the same immediate vicinity, as were several of the browse plants. These were analyzed for minor elements and for comparative purposes with several species of browse. As indicated in table 6, browse plants were considerably higher in copper than the grasses, which were apparently on the borderline or deficient in this element.

Table 6.--Minor element content of browse as compared to native grasses[1/]
(parts per million)

Plant species	Minor element content				
	Copper	Iron	Manganese	Zinc	Cobalt
Grasses:					
Pineland threeawn	4.6	50	177	10.2	0.05
Curtiss dropseed	3.9	55	385	10.0	.02
Toothache grass	4.5	56	232	13.5	.04
Browse:					
Summersweet clethra	10.6	55	653	42.0	9.90
Sawpalmetto	18.1	23	97	14.9	.07
Blackgum	6.3	61	430	12.0	5.70

1/ Analysis of single composite samples taken from one range unit in June, 1953.

Iron.--Although the iron requirement of cattle is not definitely known, the amount in most feeds is adequate (11). Browse plants were similar to grasses in this element. Since cattle grazing the experimental ranges have shown no evidence of iron deficiency, it is presumed that native forage contains adequate amounts.

Manganese.--Only traces of manganese are required for cattle. In other studies (12) heifers fed high energy rations containing 6 p.p.m. of manganese subsisted through the gestation period and gave birth to normal calves. According to this standard, all browse and the three grasses contained more than ample amounts of this element.

Zinc.--Zinc is demonstrably essential to animal life but no evidence of deficiency has been observed with cattle. Although standards are not available for comparison, browse plants of this study probably contained ample amounts.

Cobalt.--Cobalt-deficient forage contains from 0.01 to 0.07 p.p.m., whereas good forage generally contains from 0.07 to 0.30 p.p.m. (1, 10). Thus, several browse species and the three grasses tested were probably deficient in cobalt. The two plants which stand out as having an abundance of cobalt were blackgum and summersweet clethra (tables 5 and 6). During the spring and summer these plants probably supplied enough cobalt to compensate for the small amounts in the grasses. There is a strong possibility that the average forage intake was deficient in this mineral during the winter. However, it is quite likely that the cattle stored enough of this element in their bodies during spring and summer to compensate for forage deficiencies during the winter.

Little is known of the influence of minor elements on grazing habits. Cattle grazing sawpalmetto throughout the year were apparently in search of some element, for the texture or major nutrients of palmetto are not attractive;

on the contrary, the leaves are tough and fibrous and low in crude protein and phosphorus. The only outstanding feature of sawpalmetto was its high copper content, and it seems reasonable, therefore, that abundance of copper contributed to the selection of this plant by grazing cattle.

A somewhat comparable situation existed in regard to cobalt. Summersweet clethra and blackgum contained an abundance of this element, but being deciduous they were not grazed during late fall and winter. With the advent of spring, young shoots and leaves of this species were sought out rather consistently by cattle and contributed materially to intake of cobalt.

SUMMARY

Browse plants are abundant and make prolific growth in the coastal plain forest ranges of Georgia. A description of the main browse plants, an assay of their nutritional attributes, and estimates of contributions to cattle diet are presented.

Each of the 14 described plants contributed 1 percent or more to the total cattle diet sometime during the year. In all, they made up about 16 percent of the total forage intake during the winter, when other green forage was scarce. Approximately the same proportion was consumed in the spring, when succulent young shoot and leaf growth was abundant. During the summer and early fall only small amounts were eaten.

On a year-round basis, sawpalmetto was grazed more than any other species. Other important browse plants were myrtle dahoon and sweetbay magnolia during the winter, bedstraw St. Johnswort during late winter and early spring, and blackgum and summersweet clethra in the spring.

Crude protein of browse plants was slightly higher than the average amount in cattle diet during spring and summer, slightly lower in the fall, but considerably higher during the winter. Summersweet clethra, American cyrilla, blackgum, and running oak contained greatest amounts of this nutrient. Most browse plants contained adequate amounts for cattle during the spring but were on the borderline or deficient during the winter.

Lignin content of browse eaten by cattle varied from 21 percent in summer to 26 percent in winter. The high content of this practically undigestible component detracted from the value of most browse.

Ash content of browse was generally less than the composite forage sample. The reverse was true of ether extract.

Browse was relatively low in the more digestible portion of the carbohydrate fraction and, therefore, low in energy.

More than adequate amounts of calcium were found in several browse plants. However, amounts were not sufficient to compensate for deficiencies in other groups of plants.

Phosphorus content of browse differed in small amounts from other groups of plants. Red maple, American cyrilla, staggerbush, and running oak satisfied cattle requirements for phosphorus during the spring but other plants contained inadequate amounts.

Most browse plants provided ample quantities of copper during the spring and apparently enough during the winter to prevent deficiency symptoms in cattle. Sawpalmetto contained large amounts of this mineral, followed in order by running oak, summersweet clethra, staggerbush, and red maple. Several native grasses were apparently deficient in copper.

None of the browse plants appeared to be deficient in iron or zinc; they contained more than adequate amounts of manganese.

Blackgum and summersweet clethra were exceptionally high in cobalt. Enough was probably present to compensate for the low amounts in other groups of plants. Other browse species were on the borderline or deficient in this element for most of the year.

Presumably, the high copper content of sawpalmetto and the cobalt content of summersweet clethra and blackgum induced grazing of these plants.

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Agriculture--Asheville

ıtion Paper No. 76 April 1957

Forest Insect Conditions in the Southeast During 1956

by

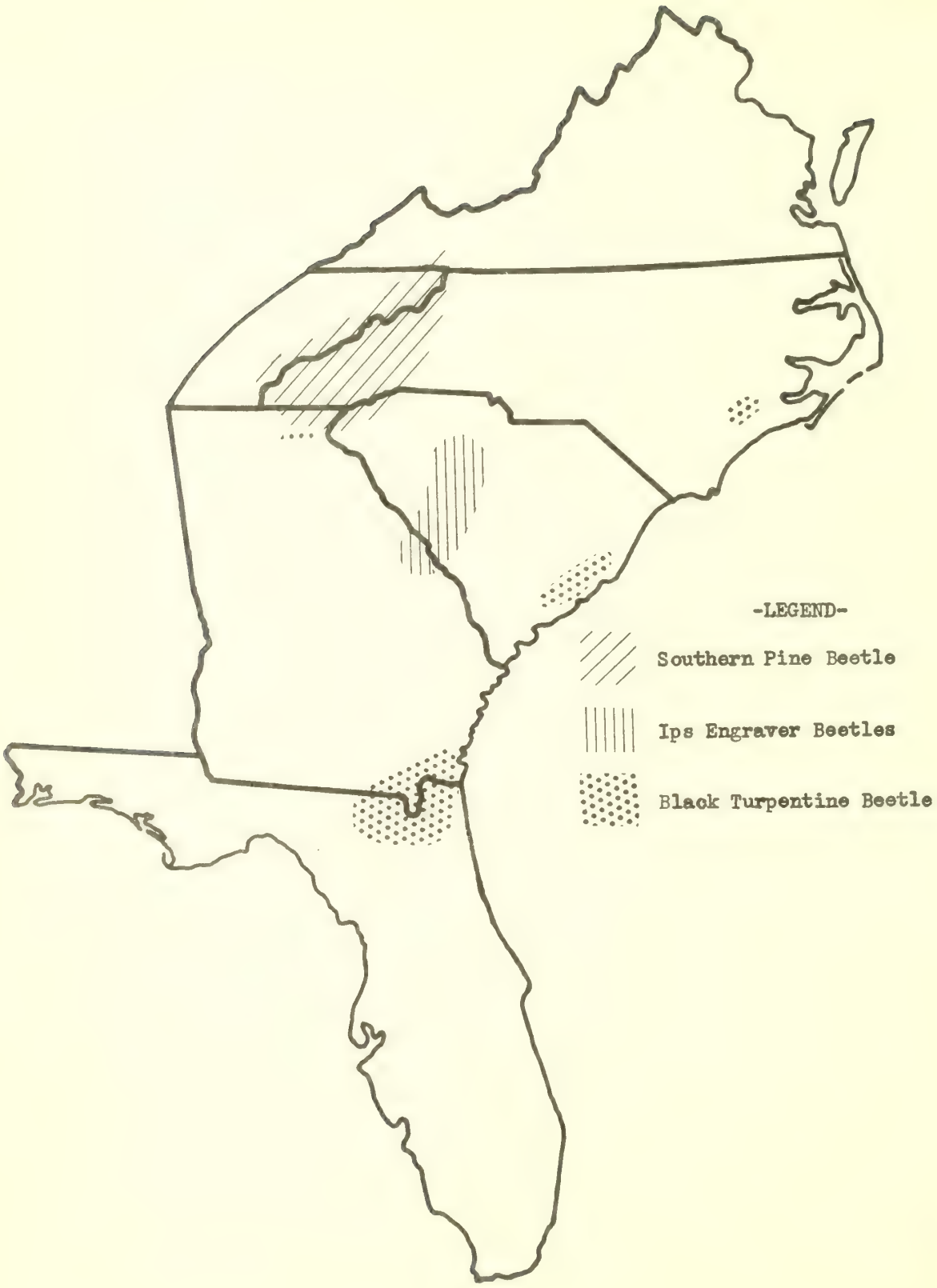
W. F. McCambridge

and R. J. Kowal

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

Joseph F. Pechanec,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE



Location of known bark beetle outbreaks in the Southeast during 1956

FOREST INSECT CONDITIONS IN THE SOUTHEAST DURING 1956

by

W. F. McCambridge and R. J. Kowal

INTRODUCTION

The southern pine beetle continued as the number-one tree killer, particularly in the Southern Appalachians, though the situation is not as serious as in 1955. Losses by Ips have been much lower than last year but are still considerably above normal; it will be remembered that record losses occurred in late 1954 and early 1955. The black turpentine beetle continued its widespread activities, with serious damage in the naval stores area though less than in 1955. Defoliator activity was more prominent than usual, particularly in hardwood. The snow-white linden moth and the variable oak leaf caterpillar were especially destructive. Less conspicuous insects such as tip moths, pitch feeding moths, and reproduction weevils presented serious problems to forest land managers.

The task of forest insect detection is dependent upon cooperation of all forest managing agencies, and this cooperation improved a great deal in the Southeast during 1956. In the States of Georgia, North Carolina, Tennessee, and Virginia, where forest entomologists or forest specialists have been employed, detection and control on state and private land has shown marked improvement (table 1). The naval stores industry, under the leadership of

Table 1.--Cooperative insect conditions reports received from federal, state, and private sources during 1956

State	Reports [1/]	State	Reports [1/]
	Number		Number
Virginia	9	Georgia	10
North Carolina	17	Florida	7
South Carolina	2	Tennessee (eastern)	3
		Total	48

1/ Methods of reporting vary somewhat in each state. Infestations on federal lands are generally reported directly to the Southeastern Forest Experiment Station. Those on private lands are largely reported to the entomologist or forester of the State Forester's office; these are summarized periodically and forwarded to the Station unless urgent, in which case an immediate report is made. A scattered number of reports are received by the Station from miscellaneous sources.

turpentine cooperatives and in cooperation with the naval stores conservation program, keeps well abreast of insect conditions and promptly reports and recommends control. Entomologists and foresters in industry and state agencies and numerous private individuals make up an ever-increasing group of cooperators who detect forest insect epidemics with increasing effectiveness. The widespread activities of the U. S. Forest Service through its ranger districts and research centers provide a major source of detection information, as do the Park Service and Indian Service. Entomologists of the Southeastern Station maintain close contact with these units and individuals in order to establish the status of destructive insects, to cooperate in making ground and aerial surveys, and to assist in control programs.

SOUTHERN PINE BEETLE

It is estimated that the southern pine beetle killed in excess of 6 million board-feet of pine timber in the Southeast during 1956. Most of this kill--5-3/4 million board-feet--occurred in the Southern Appalachian Mountains (table 2). Of the latter total, $2\frac{1}{4}$ million board-feet were salvaged, leaving a net loss of $3\frac{1}{2}$ million. During control operations against this beetle 63,368 trees were treated, 52,768 by federal agencies and 10,600 by the State of North Carolina.

Table 2.--Southern pine beetle timber losses and control during 1956 in the Southern Appalachian Mountains

Area	Pole and sawtimber volume		Trees felled and sprayed
	Killed	Salvaged	
	Thousand board-feet	Thousand board-feet	Number
North Carolina	1,700	100	28,700
South Carolina	600	360	7,500
Georgia	150	--	--
Tennessee	3,300	1,750	27,168
Total	5,750	2,210	63,368

At the end of the year, not all infested trees within control areas had been treated. Some losses may be expected to continue until artificial control measures assisted by natural agents are effective.

Virginia.--The southern pine beetle epidemic in central Virginia passed into the endemic stage during the early part of 1956. In fact, it appears that low winter temperatures early in 1955 were causing a decline in beetle populations during the autumn of that year. The outbreak is credited with causing a loss of 5 million board-feet of Virginia and shortleaf pine since it began in 1952-53.

During the fall of 1956, the southern pine beetle epidemic in northeastern Tennessee extended slightly into Virginia. Table mountain and Virginia pines were killed near Damascus. To date, losses in this area have not been serious nor are they expected to become so.

North Carolina.--The first half of 1956 marked a period of optimism concerning the trend of beetle activity in the western part of the state. Pine losses were low and the beetle was frequently hard to find. In late July, however, the beetle once more became aggressive in many areas and continued so throughout the remainder of the year. The present area of beetle activity extends from Asheville into the southwest corner of the State.

During 1956, the beetle killed an estimated 1.7 million board-feet of Virginia, pitch, and shortleaf pine. Approximately 100,000 board-feet were salvaged with a net loss of 1.6 million board-feet. A total of 28,700 trees were treated with 0.25 percent gamma benzene hexachloride in fuel oils, of which 18,100 were on federal lands and 10,600 on private lands. The latter were treated by the State of North Carolina.

Approximately 50,000 trees have been killed in the Asheville Basin since July 1956. Control efforts were possible in only a small area of the Basin, where 8,000 trees were treated by the State.

South Carolina.--Southern pine beetle activity flared up on the General Pickens Ranger District in the northwestern part of the State in late July. Small scattered patches of beetle-killed trees were widely distributed over the forest in June. By late July these spots had greatly multiplied and enlarged. Control operations were intensified in September, very greatly reducing the outbreak by the close of the year. During 1956, 7,500 Virginia, shortleaf, and pitch pines were sprayed, and 361,000 board-feet of beetle-infested timber were salvaged. Nevertheless, a net loss of over 228,000 board-feet was sustained on the district. This figure includes trees cut and sprayed. Elsewhere in South Carolina the southern pine beetle was not seriously active.

Georgia.--Persistent scattered killing of pines by the beetle has been observed in the northeast corner of Georgia. Complicated land ownership has made control impractical. It is estimated that the beetle has killed 5,000 trees during the year, which represents a loss of 150,000 board-feet.

An outbreak near LaGrange appears to be under complete control. It was checked early in May by Station personnel and salvaged by the owner soon after. Kills up to 15 acres in size were observed and over 400 cords of timber salvaged.

Tennessee.- The beetle remained aggressive in the Appalachian Mountains of eastern Tennessee throughout 1956. Pine losses on both private and federal lands have been extensive. While no volume data are available for losses on private lands, federal losses including losses sustained by the U. S. Forest Service and Park Service reached 2.6 million board-feet during the calendar year. Using such data as a guide, it is estimated that private timber lands suffered a loss of 675,000 board-feet. Of the volume killed on National Forest land, 1-3/4

million board-feet were salvaged. In an effort to reduce losses and bring the beetle in check, 27,168 trees were felled and sprayed on federal land during the year.

PINE ENGRAVER BEETLE

Persistent drought conditions are believed responsible for widely scattered high populations of Ips beetles[1/] in the Southeast. The total volume of pine being killed by this beetle is tremendous. It is estimated that mortality due to Ips beetles exceeds by many millions of board-feet the present mortality caused by the southern pine beetle. This mortality occurs as single trees or small groups of trees widely scattered over large areas, so that control is often too expensive to be practical.

Ips beetle losses were most evident during 1956 in central South Carolina and extending into Georgia. High beetle populations also caused widespread losses near the coast of South Carolina; nevertheless, in no areas of the Southeast was the beetle in a prolonged aggressive outbreak status.

Ips beetles built up large populations within badly scorched trees in the 130,000-acre area burned over in north Florida and south Georgia in March 1956. Rapid salvage operations did much to prevent insect losses in adjacent unburned stands. Ecological factors in addition to salvage reduced timber losses to a lower level than had been expected.

BLACK TURPENTINE BEETLE

The turpentine beetle continued to cause timber losses and to be generally troublesome during 1956. Very heavy beetle populations and scattered tree killing occurred near New Bern in eastern North Carolina. It is expected that timber losses will increase if present trends continue.

Turpentine beetles are numerous in logging areas in northern Georgia and control efforts were getting under way at the close of the year. Ground surveys in logging areas on the Chattooga District of the Chattahoochee National Forest revealed an infestation of over 10,000 infested stumps. Infestation rates in the logging areas surveyed ran from 75 to 92 percent of the stumps.

The beetle is entering standing trees, but to date only those trees damaged in logging are in danger of being killed.

Turpentine beetles, frequently in combination with Ips, are also troublesome in central and coastal South Carolina. In coastal Georgia and northern Florida the turpentine beetle continues to be aggressive, and widespread control in the turpentine belt is often practiced as a part of the naval stores

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1/ Ips avulsus, I. grandicollis, and I. calligraphus

operation. On the Osceola National Forest in northern Florida, 24,000 trees and stumps were treated to kill or prevent attack by the beetle. A much greater number of infested turpentine-faced trees were treated during the year on private lands.

VARIABLE OAK LEAF CATERPILLAR

During the summer white oaks throughout eastern Virginia were partially to completely defoliated by the variable oak leaf caterpillar, Heterocampa manteo. Defoliation extended from Delaware to North Carolina. White oaks in stands where this species was predominant were most severely defoliated, but no tree mortality has occurred. Pupae are abundant in the soil under trees heavily defoliated but the past history of this insect indicates that continuance of the outbreak in the same area is doubtful.

SNOW-WHITE LINDEN MOTH

For the second successive year the snow-white linden moth, Ennomos subsignarius, has caused heavy defoliation of hardwoods in northern Georgia. The epidemic expanded from 1,500 acres in 1955 to 50,000 acres this year. Of this total, 40,000 acres were classed as moderate to heavy. The looper defoliated hickory, oak, walnut, and other lesser mountain species, especially along ridges. No tree mortality has been observed to date.

Biological control agents effective in the area were investigated during latter stages of the infestation in 1956. Pupal parasitism was found to be 36 percent. Such parasitism will help to control the insect but is certainly far from sufficient in itself. Disease also appears to be causing larval mortality in some localities; combined natural control may be in the process of bringing the outbreak to an end.

FIR APHID

Chermes nusslini has been killing scattered trees along the Blue Ridge Parkway in northern Virginia for some years. The older trees are being killed and young trees are being deformed. The infestation appears limited to an area within several miles of Skyland. No great number of trees have died each year, but the amount of Fraser fir occurring along this section of the Parkway is also limited. Control in certain high value recreation areas appears necessary to prevent continued losses. Possibilities of applying artificial control measures have been investigated.

PINE PITCH MOTHS

Pitch moths, Dioryctria spp., continue to be a general nuisance and in some instances become serious tree-damaging agents. Dioryctria amatella attacked and killed 70 percent of all growing tips of slash pine in one area of southern Georgia. Trees of pulpwood size and larger were attacked.

Dioryctria is frequently confused with the black turpentine beetle in those instances when the moth attacks either fresh wounds or near turpentine faces. Pitch moth attacks in such cases result in partial girdling and weakening of the trees, creating more favorable host material for the turpentine beetle.

PINE REPRODUCTION WEEVILS

Severe infestations of reproduction weevils have been reported from scattered locations in the Southeast. In the mountain areas, Hylobius pales appears to be far more common than Pachylobius picivorus, which seems to be predominant further South.

NANTUCKET PINE MOTH

The pine moth, Rhyacionia frustrana, continued at the same or increased levels in all the states in the Southeast. Plantations of shortleaf and loblolly pine have been observed with as much as 80 percent of the developing shoots attacked. It is not unusual to find severely infested trees up to 20 feet in height.

FOUR-EYED SPRUCE BARK BEETLE

A severe 10- to 15-acre blowdown of overmature red spruce and Fraser fir occurred on the Blue Ridge Parkway on March 8 in the vicinity of Mt. Mitchell, North Carolina. Attacks by the four-eyed spruce beetle, Polygraphus rufipennis, occurred soon after. Periodic inspections throughout the summer and fall revealed no unusual buildup of this insect that might endanger standing trees.

PINE SAWFLIES

Pine sawflies, Neodiprion spp., were at a relatively low level. Several years ago damage was severe in parts of South Carolina.

Considerable defoliation by pine sawflies was reported from forested areas in the vicinity of Chattanooga, Tennessee. However, specimens were not received to permit identification, and the report was obtained too late to permit collection of the insect. No mortality resulted from this defoliation.

PINE NEEDLE MINER

Activity by a pine needle miner, Exoteleia sp., during early summer marked the third year of infestations on pitch and shortleaf pine in the North Carolina-Tennessee mountain area. While the defoliation apparently has no serious effects on the trees, it causes a discoloration suggesting mortality associated with bark beetles.

TORTRICID MOTH ON LOBLOLLY PINE

Rather severe damage to loblolly pine in a forest nursery in Virginia was caused by Sparganothis sulphureana Clem. (Tortricidae) in the spring. The insect webs needles together and chews them extensively. (Considerable malformation by this insect of Scots pine below 2 feet in height has been reported from southern Ontario.)

COLUMBIAN TIMBER BEETLE

Rather severe damage to yellow-poplar occurred in southeast Virginia and near Lenoir, North Carolina. The damage was observed in early June. In North Carolina, infested stands are second-growth poplar ranging from 6 to 18 inches d.b.h. An over-all infestation of 5 to 10 percent of the trees was estimated for the area, although the degree of infestation varies greatly. Two to four attacks per tree were common; 28 attacks were observed on one 14-inch tree. During the initial reconnaissance survey it was learned that some mill operators in the area were taking considerable financial loss in degrade. These operators mentioned price drops of from $105 to $65 per thousand board-feet. More information is needed to determine the causes of this condition and its importance.

ELM LEAF BEETLE

Dipterous parasites of the elm leaf beetle were released during the period July 25 to August 3 in Virginia to combat this defoliator. Releases were made by Beltsville Forest Insect Laboratory in cooperation with other interested parties.

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May 1957

New Spray Puller for Turpentining

. . . and how to use it

by Ralph W. Clements

SOUTHEASTERN FOREST EXPERIMENT STATION
Asheville, North Carolina

Joseph. F. Pechanec,
Director

U. S. Department of Agriculture - Forest Service

NEW SPRAY PULLER FOR TURPENTINING

And How to Use it

by

Ralph W. Clements
Lake City Research Center

INTRODUCTION

For the first time since the development of bark chipping, a highly satisfactory tool for bark pulling and acid treatment of high faces is now available for gum naval stores production. Although a spray-puller has been on the market for several years,[1/] it has never performed satisfactorily because of weaknesses in the design. This tool has been redesigned and all of the known objectionable features have been eliminated.

DESCRIPTION OF THE BARK-PULLER

The basic parts of the spray-puller are the pulling blade, the aluminum tubing stock, and the plastic spray mechanism.

The new bark-pulling blade.--The improved puller blade has been designed and developed to remove all of the bark, cut a clean streak, and in general to make bark pulling easy. The new blade and its critical dimensions are shown in figure 1.

In designing the new blade, a major change was made in the width of the bill. At the cutting edge, the bill is now 1/8 inch wider than the throat at the rear of the blade. This gives a flare to the blade at the cutting edge. As a result, the cutting edges actually "lead" into the bark. No pressure is required to hold the edges against the exposed wood, and the stock riding against the tree will not force the edges away from the streak and the line of cut. If the cutting edges bite too deeply into the wood, the lower bottle end need only be swung away from the tree. The same principle is used to regulate the streak depth in either wood or bark chipping.

The 3/4-inch jaw determines the height of each streak pulled. The blade and its angle of attachment to the clamp have been designed for the jaw to run along the exposed wood and to cut a clean streak. The blade has not been designed for the wide part of the bill to run along the wood of the tree. Correct position of the blade for pulling a streak is shown in figure 2.

1/ Ryberg, M. E., and Burney, H. W. An Acid-Spraying Puller for Naval Stores Production. Jour. of Fla. Eng. Soc. 5(3): 15-27. 1951.

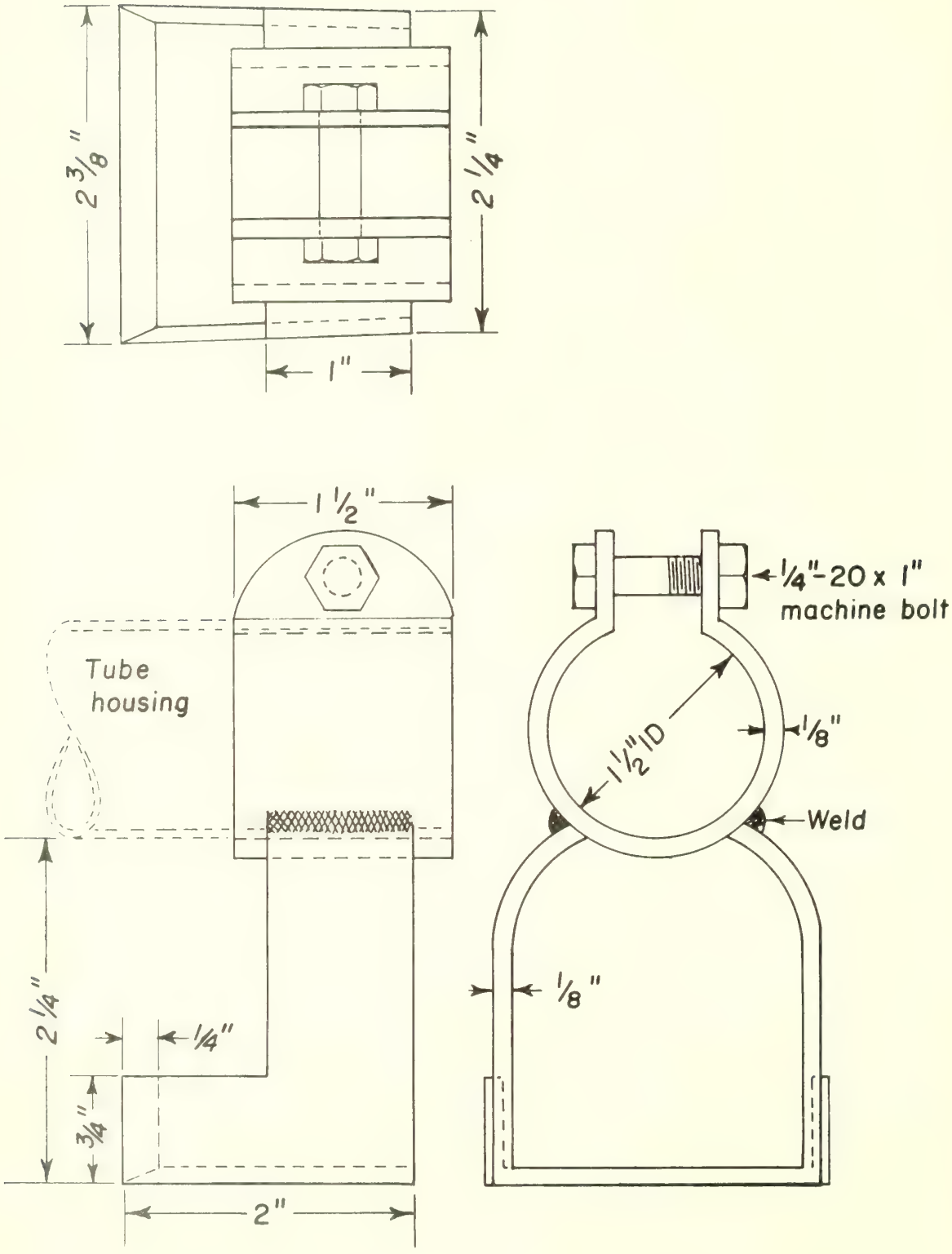


Figure 1.--Improved puller blade with ring clamp for mounting on Evans spray puller.

Figure 2.--Correct position for using the improved puller blade. The 3/4-inch jaw rides against the wood of the tree.

Spray mechanism.--The plastic parts which make up the sprayer mechanism of the spray-puller are shown in figure 3. Each piece is identified by a descriptive name which has been accepted as standard.

The baffle has been redesigned and greatly improved. It fits in the nozzle and serves two important purposes; (1) it permits filling the trap with acid when the tool is inverted, and (2) it retards the sloshing of acid from the nozzle when the streak is pulled. The baffle is an essential part of the sprayer mechanism and it never should be discarded as unimportant.

The compression sleeve of the acid trap has been substantially reinforced to prevent splitting, to hold the connector tube in place, and to prevent leakage inside the aluminum stock.

Drawings and specifications for all molded, plastic parts can be found in the appendix.

New pullers available in three lengths.--Spray pullers are now available in three lengths--36, 48, and 60 inches. The economical 36-inch length was designed primarily for the producer who must turn to pulling to finish working out the fourth year on timber leased for 4 years. When the producer turns from chipping to pulling, and he plans to work his timber for the fifth year, it is recommended that he purchase the 48-inch length. If he knows the pulling work will continue into the sixth year, it is recommended that he purchase the 60-inch offset model.

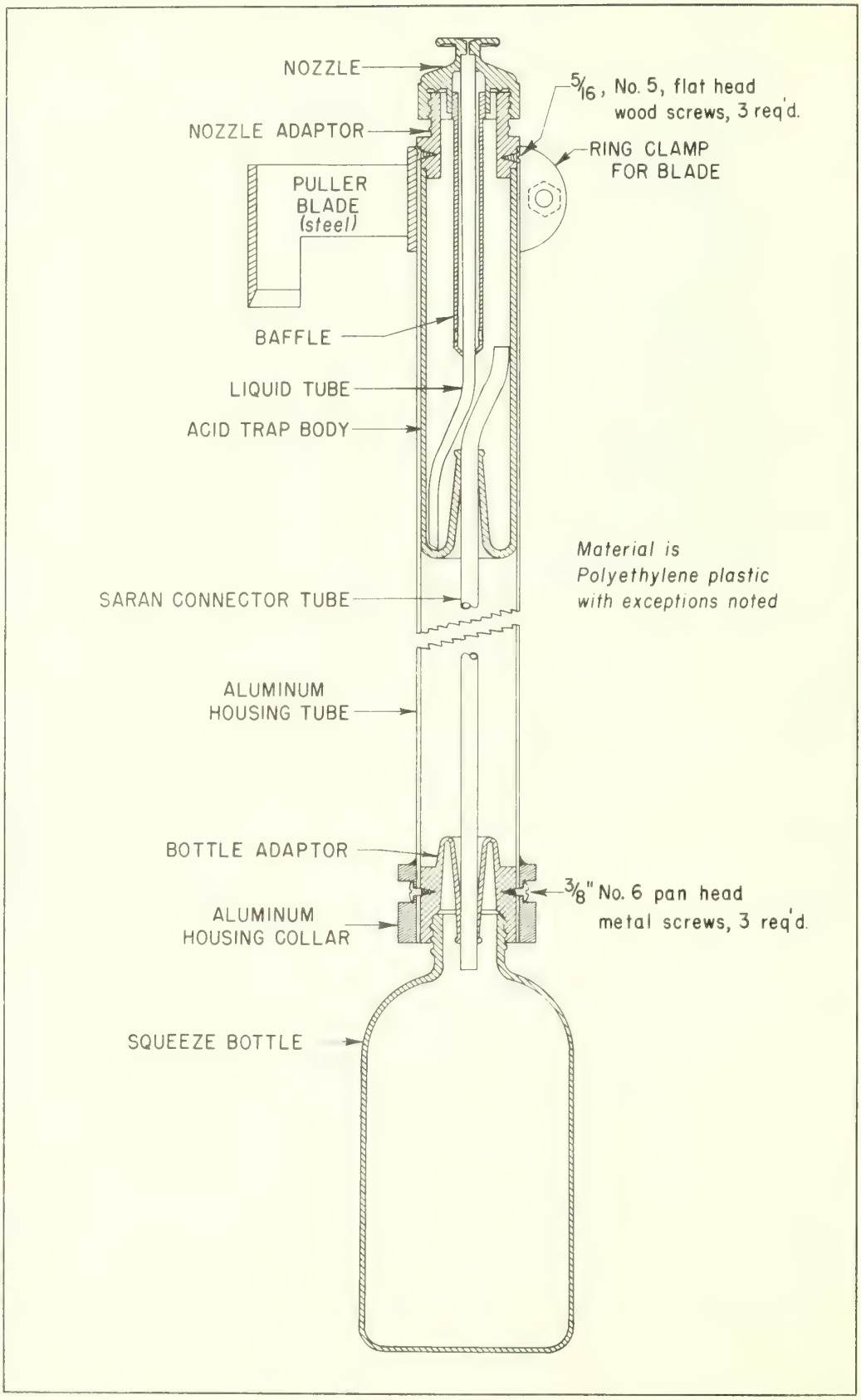


Figure 3.--Cutaway view of spray puller, showing assembly of plastic parts.

The three spray-pullers, each with a description for ordering, are shown in figure 4. All lengths work satisfactorily on low pulling faces like those encountered in the second half of the fourth year of work. Higher faces require the longer lengths. After the number of years of work has been specified by a naval stores producer, the puller can be selected which fits the proposed plan of work.

Cost of the pullers varies with the length of the stock. The cost of all new models has been reduced well below that of the previous model.

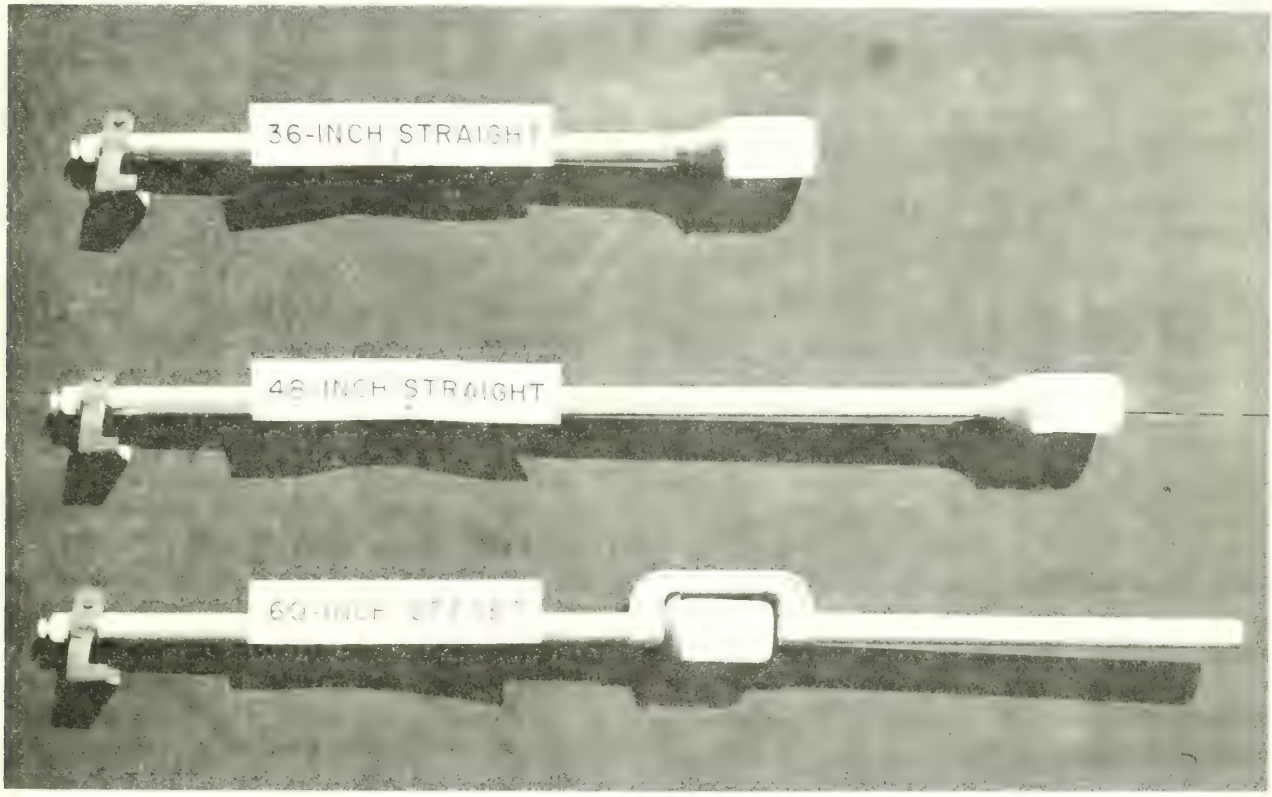


Figure 4.--Commercial spray-pullers now available in three lengths.

MAINTENANCE AND CARE OF THE SPRAY-PULLER

The nozzle, baffle, and liquid tube should be removed occasionally from the acid trap for cleaning. Do not try to cut away hardened gum from around the nozzle-opening with a knife. First, soften the gum with kerosene, then carefully scrape away the gum. Do not enlarge the nozzle opening with wire or any metal object. Remove gum from the nozzle opening with a toothpick or a sharpened, wooden match stem.

Before replacing the nozzle assembly, remove the bottle and flush the acid trap thoroughly with clean water to remove particles of trash caught in the trap. Bits of bark, pine straw, or other solid material will clog the air gates of the nozzle and the sprayer will not work. Drain all water from the trap before replacing the nozzle assembly or the bottle.

After cleaning, the liquid tube should be inserted first in the nozzle for reassembly, then the baffle is slipped over the liquid tube and pushed firmly in place. In attaching the nozzle assembly to the acid trap, the liquid tube should be located on the side of the trap opposite the connector tube. See figure 3 for a cutaway view of the acid trap revealing the position of both liquid and connector tubes.

Do not attempt to remove or adjust the connector tube. The distance this tube extends into the trap governs the amount of acid caught in the trap. All acid in the trap above the tube will flow back into the bottle. The tube is permanently placed by the manufacturer at the time of assembly.

The acid trap is held in place by three special, metal screws. These screws are located at the top of the aluminum-tubing stock. When the puller blade is attached, the ring clamp slips over these screws and hides them from view. These screws should never be removed, and care should be taken to prevent acid from reaching them. If screw heads are eaten away by acid, the trap will turn when an attempt is made to tighten the nozzle.

The bottle adaptor is held in place by pan-head screws. These screws prevent the adaptor from turning when the bottle is tightened for a leak-proof fit, and should not be removed. They are located at the lower end of the stock, and acid should never reach them.

Since both acid trap and bottle adaptor are permanently anchored inside the stock, these two parts should not be removed for cleaning. If leakage occurs inside the stock, return the entire-spray puller to the manufacturer for repairs.

The puller blade, ring clamp, and clamp bolt are metal, and will corrode if they are left exposed to sulfuric acid. Before placing a new puller blade in use, it is recommended that the blade, the clamp, and the bolt be coated with gum taken directly from the turpentine cup. This coating of gum will lessen the corrosive action of the acid on the new and clean metal parts.

HOW TO USE THE SPRAY-PULLER

The bark-pulling method requires more skill, patience, and time than bark chipping and treating. Bark pulling must remove both outer and inner barks, and each streak must remove the acid-killed tissues. Then the right amount of acid must be correctly placed if the bark-pulling method is to prove effective.

Height of pulling streaks.--On most fifth- and sixth-year pulling faces for both slash and longleaf pine, a streak 3/4 inch high will give good yields when pulled and treated every 14 days. But good acid treatment is necessary, and penetration of the acid above the streak should range from 1/2 to 3/4 inch.

Peaked faces best.--In bark pulling and acid treatment, peaked faces will save the laborer much time at each tree and increase the number of faces he works each day. Slanted streaks require too much footwork in moving around the tree and are more difficult to treat.

Acid treatment of pulling streaks.--Sulfuric acid treatment has the same effect on streaks of pulling height as it does on streaks of chipping height. A bark streak at pulling height, if correctly treated with 50-percent sulfuric acid, will produce as much gum as two untreated, wood-pulled streaks. It is the acid that prolongs the flow of gum and gives good yields; therefore careful application is required on the pulling streaks. Poor gum yields from the bark-pulling method usually can be traced directly to poor and spotty acid treatment of the streaks.

Good treatment is more difficult to obtain on pulling faces than on faces of chipping height. It requires a little better aim and a little slower movement of the nozzle down the streak than with the hand-sprayer. The puller stock must be carefully handled so that the acid is sprayed along the juncture of wood and bark. In treating a high pulling streak, always start at the shoulder and move downward to the peak. Never start at the peak and move upward. It is much easier to steady and guide the puller nozzle as it moves down the peak. Movement of the nozzle down the streak should be slow enough to thoroughly wet the under-side of the bark and the exposed wood.

Hazards eliminated.--It is dangerous to try to treat high pulling streaks with the hand squeeze sprayer, and the treatment is seldom very effective. To reach the fresh streak, the laborer has to stand close to the tree, directly under the streak, and the acid spray blows or drifts down on his head or his clothes. The laborer is under physical strain trying to reach the high streak. He hurries his pass at the streak with the sprayer to get away before the acid drifts on his clothes, and poor coverage of the streak usually results.

With the specially designed spray-puller, laborers are able to back away a safe distance from the tree for treatment (fig. 5). Even on windy days when blow-back is the greatest, this tool reduces the hazards of treating streaks on high faces.

Operation of spray mechanism.--Fill the plastic bottle only two-thirds full of acid. Air space must be left at the top of the bottle. Do not strip the threads in the bottle adaptor by excessive tightening of the bottle. Only a moderately tight twist of the bottle is required to give a leak-proof fit.

It is impossible, by hand-squeeze, to force acid the length of the stock from bottle to nozzle. To provide adequate and easy discharge of acid by hand-squeeze, an acid trap is located at the upper end of the stock. This trap acts as a reservoir and stores about 35 cc. of acid. When the plastic bottle is squeezed, acid is forced from the trap up the liquid tube and out the nozzle.

Figure 5.--Laborer shown treating bark-pulled streak with 48-inch spray-puller. Tree is in its fifth year of work and streak is 8 feet from ground, yet laborer stands safe distance from tree for treatment.

Figure 6.--Correct position for holding spray-puller to fill trap with acid.

The trap is filled by inverting the tool and pointing the nozzle at the ground (fig. 6). Air space must be present in the top of the trap, so the connector tube is permanently set and the trap will never fill over half full. Continuous acid drip at the nozzle will indicate the trap is filled to its capacity. However, the trap will not retain the acid unless the baffle is securely in place in the nozzle. The baffle must form a leak-proof fit, or acid will leak out the nozzle opening. While in use in the woods, the trap should be refilled after treating about 10 to 15 trees. Then the supply of acid in the trap will be kept at the proper operating level. The refilling can be done while the laborer walks from tree to tree.

If acid is not discharged from the nozzle when the bottle is squeezed, make the following checks:

1. Be sure there is a supply of acid in the trap. When the trap is properly filled (half full), less pressure is required on the bottle for a quick discharge of acid with a good delivery rate. The flow of acid from bottle to trap may be hastened by a slight squeeze on the bottle while the nozzle is tilted downward.

2. Be sure liquid tube is firmly in place in the nozzle.

3. Check nozzle and bottle threads for possible air leaks. Tighten each sufficiently to stop air leaks.

4. Be sure that nozzle is clean and that no trash is in the trap.

5. Do not trim liquid or connector tubes in an attempt to improve the spray characteristics. The source of the trouble is not in these tubes.

The sprayer mechanism should be tested with water and these operating hints demonstrated to each laborer before assigning the tool for woods use.

The improved spray-puller is designed to give years of trouble-free service. Each tool is tested and guaranteed when it leaves the manufacturer's assembly line. The plastic parts should never wear out, but they can be damaged by abuse in the woods and improper care. Most spray-puller failures can be traced directly to abuse in the woods and tampering with the sprayer mechanism by unqualified persons.

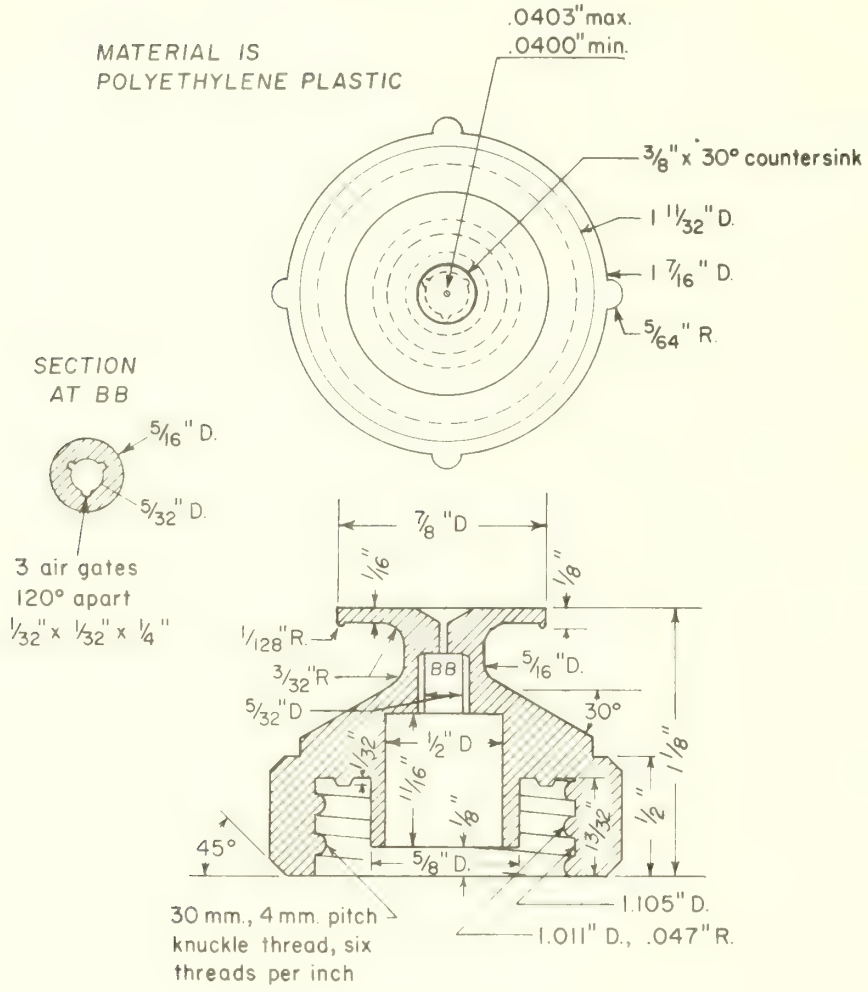
POINTS TO REMEMBER

1. Fill bottle two-thirds full
2. Don't strip threads on bottle
3. Check liquid tube for tight connection
4. Check nozzle and bottle threads for air leaks
5. Fill acid trap by tilting nozzle toward ground
6. Keep nozzle and trap clean
7. Do not attempt repairs in woods

APPENDIX

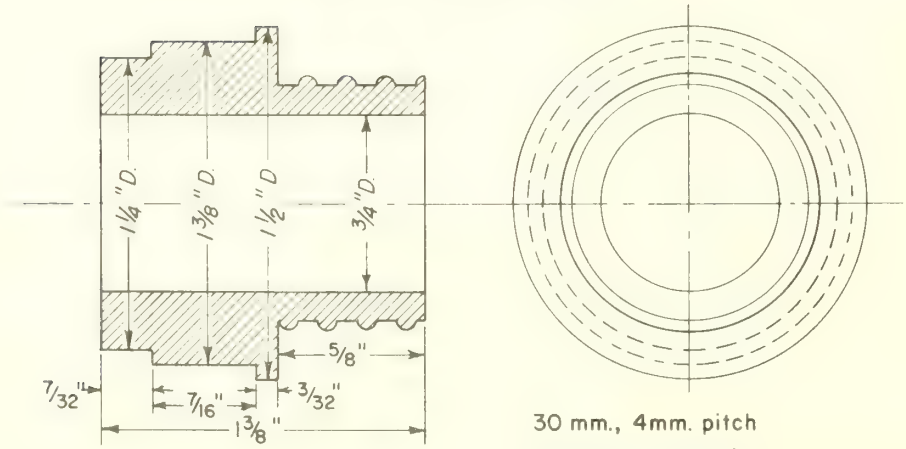
Detailed working drawings for construction of the molded polyethylene parts for the spraying mechanism.

SPRAY-PULLER NOZZLE



NOZZLE ADAPTOR

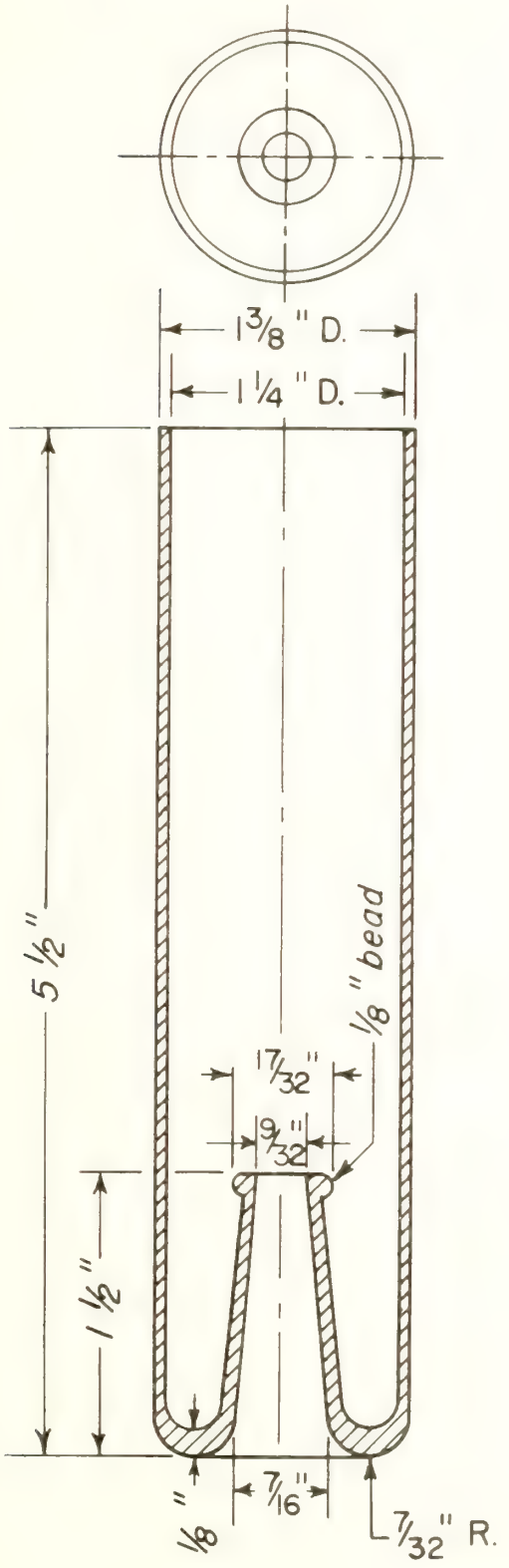
POLYETHYLENE PLASTIC



Nozzle adaptor is plastic
welded to acid trap body

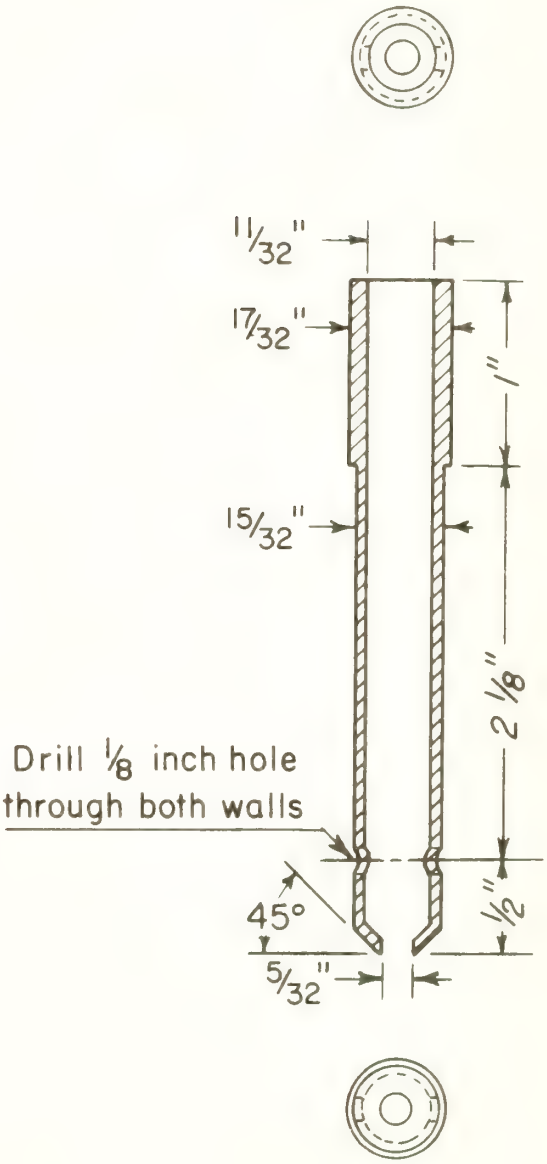
ACID TRAP BODY

POLYETHYLENE PLASTIC



BAFFLE

POLYETHYLENE PLASTIC



BOTTLE ADAPTOR

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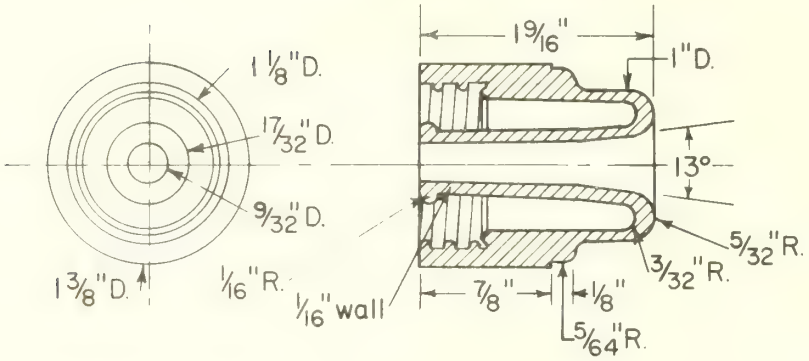
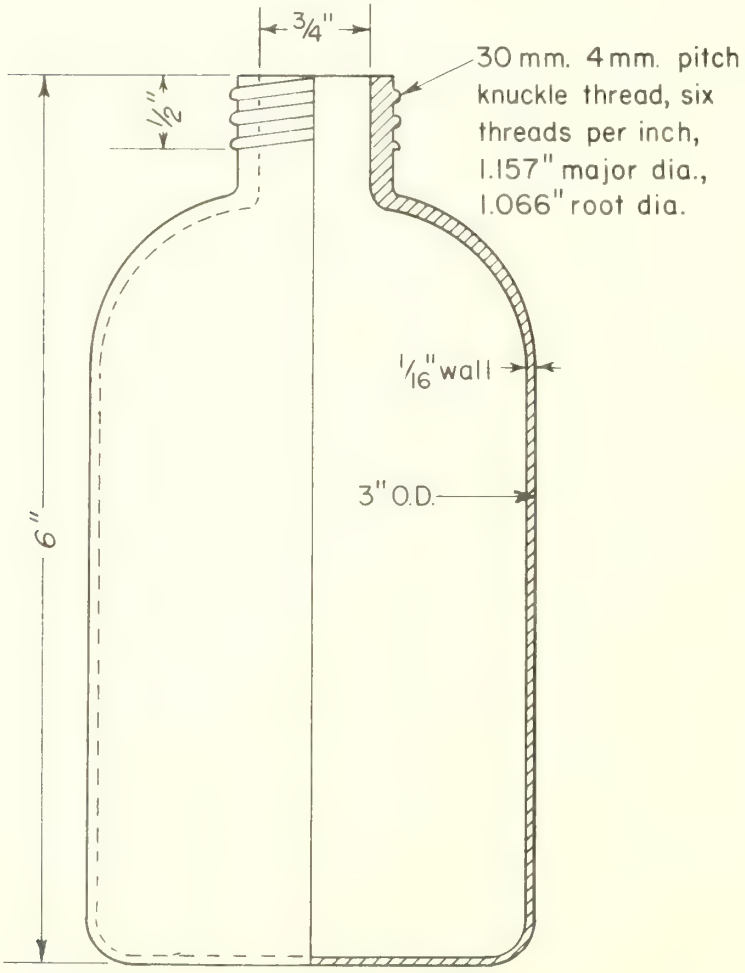


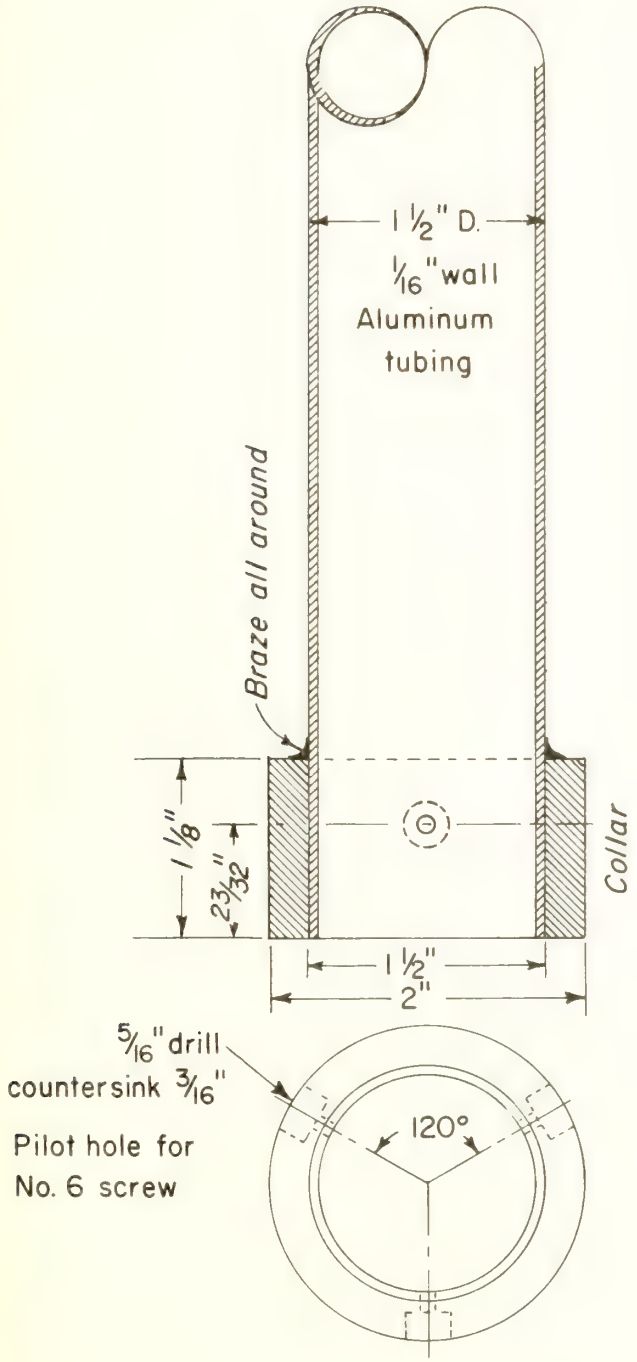
SQUEEZE BOTTLE

POLYETHYLENE PLASTIC

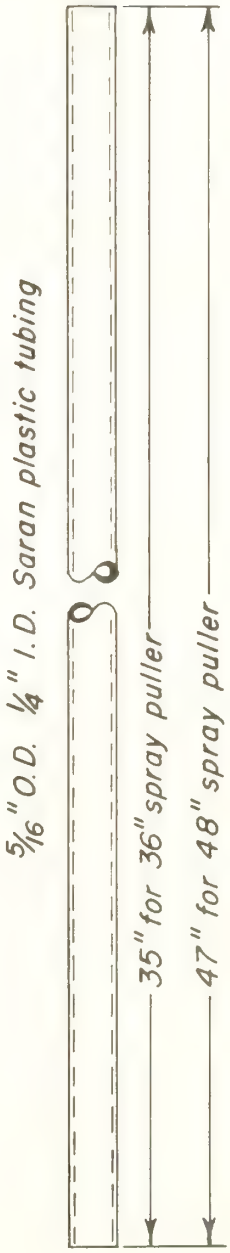


PULLER HOUSING AND COLLAR

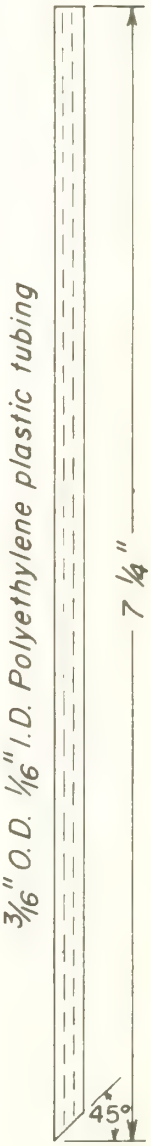
ALUMINUM TUBING



CONNECTOR TUBE



LIQUID TUBE



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Some Results of Seeding and Fertilization to Improve Southern Forest Range

by

L. K. Halls, G. W. Burton,

and B. L. Southwell

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

Joseph F. Pechanec,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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This is a cooperative investigation by the University of Georgia Agricultural Experiment Stations, Coastal Plain Experiment Station, and the following agencies of the U. S. Department of Agriculture: Southeastern Forest Experiment Station, Forest Service; Forage and Range Section, Field Crops Research Branch, Agricultural Research Service; and Animal and Poultry Husbandry Branch, Agricultural Research Service.

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SOME RESULTS OF SEEDING AND FERTILIZATION TO IMPROVE SOUTHERN FOREST RANGE

by

L. K. Halls, G. W. Burton, and B. L. Southwell [1/]

INTRODUCTION

Several million acres of cutover longleaf-slash pine forests have long contributed to the beef cattle industry of the Southeast. These forests often provide forage for cattle through the entire timber rotation. Although large quantities of forage may be produced, beef production is limited because the infertile soils do not produce high quality native forage palatable to cattle. Quality, quantity, and palatability of forage could seemingly be improved through the application of fertilizer and replacement of the less desirable species with more nutritious tame forage plants.

The tests reported herein were an endeavor to improve forest range by eliminating the relatively low quality native forage and seeding to desirable tame pasture plants adaptable to the coastal plain region. Improvement practices involved land preparation, fertilization, and artificial seeding. Treatment was evaluated by measuring the response of tame and native forage plants, pine seedling establishment and survival, and animal weight changes.

Several fertilization and reseeding studies have been conducted in the pine forests of south Georgia and north Florida. Blaser and Boyd (1) established clovers and grasses in virgin sods of the flatwoods by burning the herbaceous vegetation, fertilizing, seeding, and controlling competing vegetation by grazing. More recently, Killinger (5) showed that mineral and protein content of wiregrass was increased after the range had been burned and complete fertilizers and lime applied.

Work by Burton and Mathews (3) produced valuable information on proper species, land preparation, and fertilization and liming needed for seeding Georgia flatwoods. Louisiana white clover, common lespedeza, Dallisgrass, and carpetgrass were outstanding species on sandy soils. A relatively high level of fertility was indicated for best growth of white clover and Dallisgrass, whereas common lespedeza and carpetgrass responded well with relatively low fertility. Halls and Suman (4) showed that Louisiana white

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1/ Respectively, Range Conservationist, Southeastern Forest Experiment Station, Forest Service, USDA; Principal Geneticist, Field Crops Research Branch, Agricultural Research Service, USDA; and Animal Husbandman, University of Georgia, Coastal Plain Experiment Station.

clover, carpetgrass, and Dallisgrass could be established without tillage in longleaf-slash pine forests when litter was removed by burning and when fertilizer and lime were applied. Carpetgrass stands improved with close grazing, whereas Dallisgrass declined. Nearly all native species were eliminated.

Studies by Woodhouse and Lovvorn (7) in North Carolina and by Burton and Mathews (3) in Georgia suggested that big trefoil was a legume well adapted to the flatwoods of these states. The latter studies showed that native vegetation did not compete seriously with big trefoil, which had the great merit of affording green forage throughout the year.

Observations from exploratory tests by the authors at Alapaha, Georgia, revealed the excellent possibilities of big trefoil and Dallisgrass for improving forest range under a relatively high level of fertility. Dallisgrass was successfully introduced into flatwoods by seeding alone or by overseeding on stands of big trefoil. Heavy trampling and close grazing during establishment were not detrimental to big trefoil or Dallisgrass. Both species were highly palatable, and had a long season of growth. When beyond the seedling stage, big trefoil made acceptable regrowth following accidental burning.

Carpetgrass and common lespedeza are widely distributed and well adapted to the coastal plain of Georgia (6). Carpetgrass is fairly palatable but when unfertilized is not nutritious enough to produce finished animals. Common lespedeza is the most widespread legume found with carpetgrass on unimproved flatwoods. Stephens (6) describes it as furnishing excellent feed from early July to the first killing frost. Common lespedeza reseeds well, and in mixtures with carpetgrass furnishes good grazing.

Burton and Mathews (3) indicate that although common lespedeza will grow on unfertilized soils, better growth is obtained when potassium and phosphorus are applied. Working with carpetgrass, Blaser and Stokes (2) showed that light applications were instrumental in promoting greater yields. Accordingly, carpetgrass and common lespedeza with a relatively low rate of fertilizer seem an excellent low-cost combination which owners with limited means could logically use to improve native ranges for grazing.

These studies prompted the selection of a grass-legume combination of carpetgrass and common lespedeza to be tried at a fairly low rate of fertility in the present experiment. Plants selected for comparison at a higher rate of fertilization were Dallisgrass and big trefoil.

THE AREA

The 40-acre study area is located near Alapaha in the upper portion of the "flatwoods" section of the Georgia coastal plain. The terrain is nearly level, with 0- to 2-percent slope, and an elevation of 293 feet. The three main soil types are Lakeland loamy fine sand, Lynchburg loamy fine sand, and Plummer sand. These soils are well drained, moderately well drained, and very poorly drained, respectively. All soils are strongly acid and inherently low in fertility.

The average frost free season extends from March 10 to November 17. Average annual precipitation is 48 inches. Precipitation in excess of 0.01 inch occurs on the average 100 days throughout the year, and rainfall in excess of 0.50 inch for 32 days in each year. Most frequent showers and heaviest rainfall normally take place during July and August. Precipitation records for the study period are included in appendix table 7.

Tree overstory consisted of a medium to heavy stand of pole size longleaf and slash pine trees with a few scattered loblolly pines and scrub oaks.[2/] Gallberry was the principal shrub. Scattered throughout were sawpalmetto, staggerbush, runner oak, southern waxmyrtle, huckleberry, and sand blackberry.

Main herbaceous understory species were pineland threeawn, Curtiss dropseed, various bluestems, panicums, carpetgrass, and miscellaneous grasses.

TREATMENTS

Prior to 1949 the experimental area had been periodically burned during the winter. Cattle had grazed the area since 1943. In June and July 1949, a seed tree cutting removed all but approximately six to eight pine seed trees per acre. Debris was piled and the entire area burned over in November. The area was then divided into four 6-acre and four 4-acre range units (fig. 1).

On two of the 6-acre and two of the 4-acre units half of each was double disked with a bush-and-bog harrow to prepare the land and eradicate shrubs; the other half was cut with a Marden rotary brush cutter. The remaining four pastures had no land preparation other than burning.

A "moderate" rate of fertilizer and lime was applied to the four 4-acre units. One ton of lime, 60 pounds of phosphate (P_2O_5), and 60 pounds of potash (K_2O) were spread in December 1949. The same amount of fertilizer was added the following March. Maintenance consisted of refertilization with 60 pounds each of phosphate and potash every fall. These same units were broadcast seeded to big trefoil at the rate of 3 pounds per acre in February, and Dallisgrass at 10 pounds per acre in March 1950.

A "low" rate of fertilizer, 30 pounds per acre each of phosphate and potash, was applied to the four 6-acre units. This basic rate was added annually in the spring. These units were broadcast seeded to common lespedeza and carpetgrass, plants capable of thriving with relatively little fertilizer, at the rate of 5 and 3 pounds per acre, respectively, in March 1950.

EVALUATION OF TREATMENTS

The effectiveness of ground preparation, fertilization, and seeding in improving range condition was evaluated by examination and records of changes in vegetation, and by cattle weight changes.

2/ Common and scientific names of plants are listed in appendix table 8.

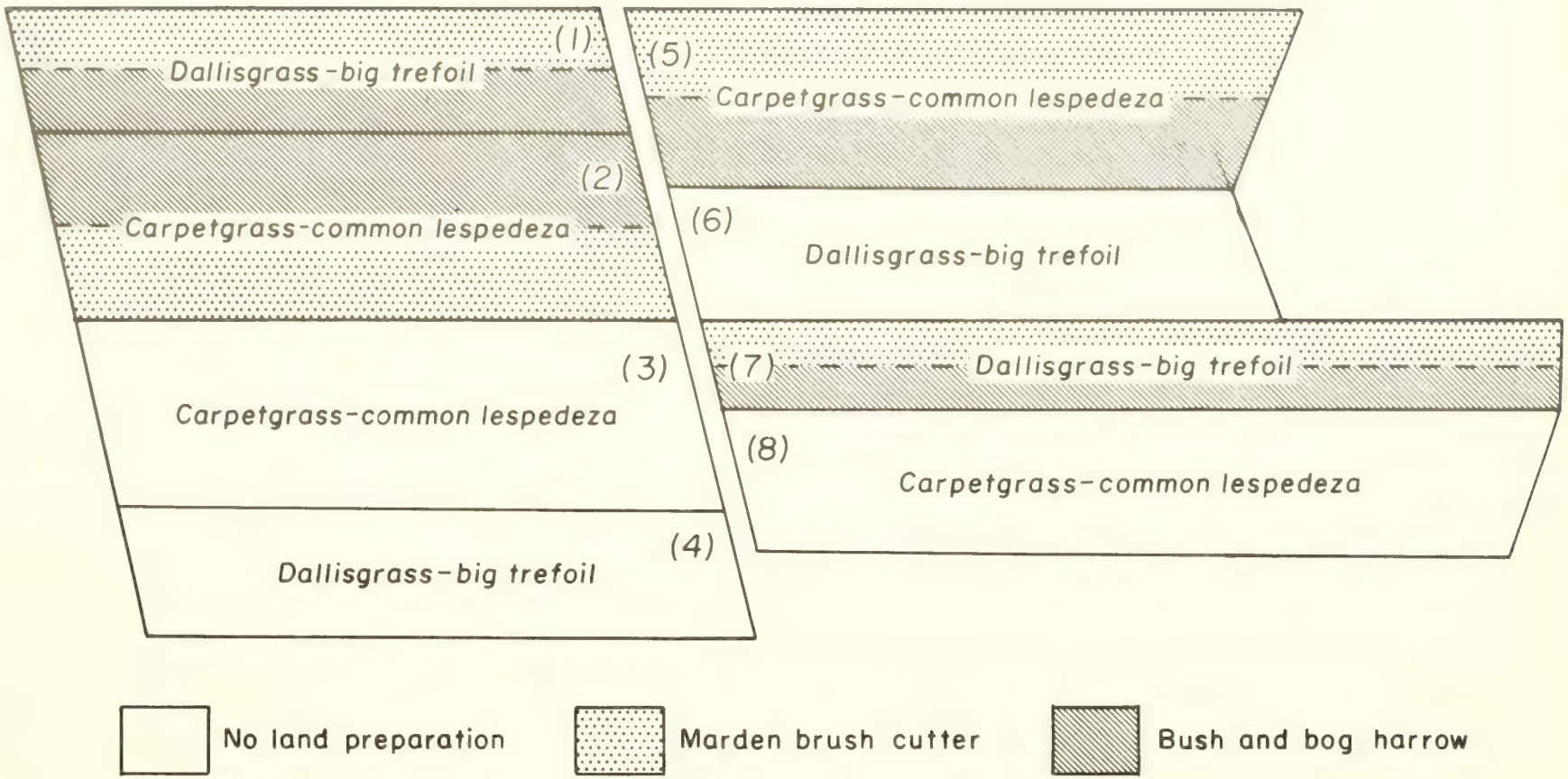

Figure 1.--Experimental tract at Alapaha, Georgia.

Herbaceous ground cover by species was measured by sampling four temporary and randomly distributed 100-square-foot circular plots per acre. Inventories were taken before treatments were applied and again in the fall of 1950, 1951, 1952, and 1954. Periodic observations were made each grazing season to assess the availability and contribution of each tame pasture plant to the cattle diet. In addition each species was rated according to number of plants per unit area. A classification of 1-2 indicated an excellent stand or maximum number of plants per unit area. A 3-4 indicated good stands, 5-6 fair, 7-8 poor, and 9-10 a failure.

Cattle weights were obtained at 28-day intervals from mid-March to mid-October. In 1950, 18 Brahman-Hereford cross heifers moved without restriction through all units for 52 days during the period. In 1951, two Brahman-Hereford cross yearling heifers grazed each unit. From 1952 to 1954 inclusive, animal numbers were regulated at 28-day intervals according to forage availability. A minimum of two animals were left on any one unit during the grazing season. Beginning and final dates of grazing were determined by the stage of growth and availability of forage. Heifers were sprayed for insect control as needed. A mixture of equal parts of steamed bone meal and salt was accessible at all times.

Because investigations were conducted on lands that could presumably be partially or fully stocked with timber, it was deemed desirable to measure pine seedling response to the various treatments. Accordingly, 500 slash pine seed were broadcast on two 1/100-acre grazed and ungrazed plots per unit in January of 1953. Survival counts were taken at beginning and end of grazing season in 1953 and 1954. Success of natural seeding from seed trees was by observation through 1953, after which sixteen 100-square-foot circular plots per unit were inventoried for slash and longleaf pine seedlings.

BEHAVIOR OF RESEEDED FORAGE PLANTS

Dallisgrass

The initial seeding of Dallisgrass on undisturbed sod yielded a meager amount of plants. In an effort to determine whether it might still be possible to get a satisfactory stand of this species, the areas were reseeded in the spring of 1951 and again in 1952. Plant numbers were augmented slightly after each seeding but not sufficiently to produce a desirable coverage. Only a few plants survived after the first year, and by 1954 Dallisgrass had practically disappeared (fig. 2).

Several factors contributed to the poor showing of Dallisgrass on undisturbed sod. Seed often failed to contact the mineral soil. Light grazing the first year after planting did not eliminate competition of native species over most of the area. Carpetgrass soon invaded closely grazed areas and competition from this species not only inhibited Dallisgrass in becoming established, but crowded out a good portion of the existing Dallisgrass. Only in localized areas where slash and debris had been piled and burned and where intense fires of relatively long duration had destroyed the native vegetation did Dallisgrass become established.

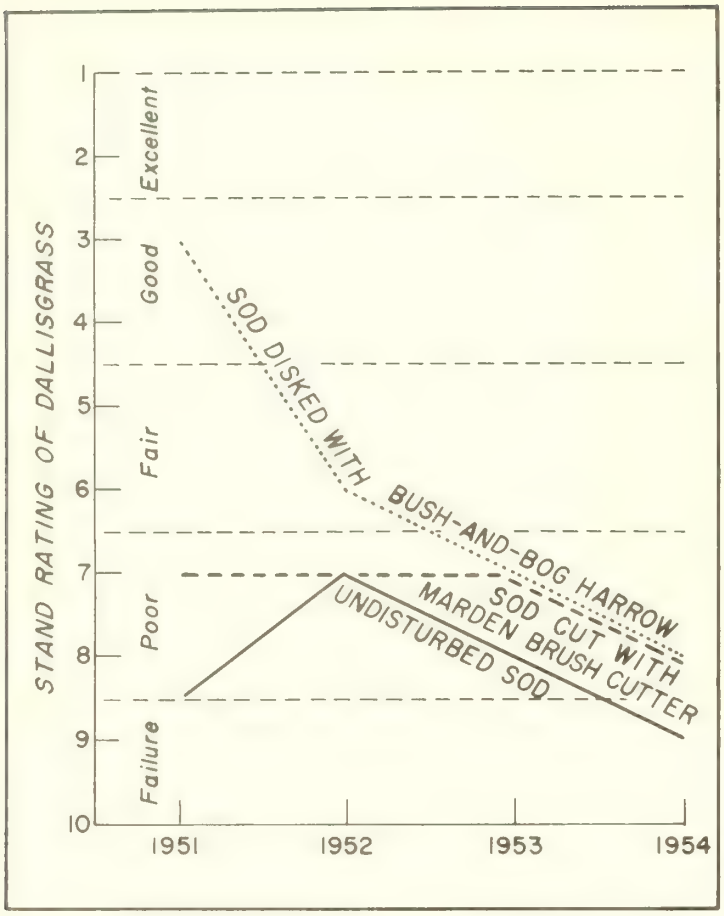

Figure 2.--Dallisgrass establishment was facilitated by land preparation. Infertile soil and competition from carpetgrass hindered perpetuation of this species.

Land preparation definitely aided establishment of Dallisgrass. The degree of success was dependent on the extent to which mineral soil was exposed and competition from native vegetation eliminated. The bush-and-bog harrow completely broke up the sod and practically destroyed all native vegetation; as a result good stands of Dallisgrass were obtained. The effect of the Marden brush cutter on soil and vegetation was less pronounced, and consequently fewer Dallisgrass plants became established. Half of each of these ranges were recut with the Marden brush cutter and reseeded to Dallisgrass in February 1952. This seeding was largely unsuccessful because of competing vegetation.

Good surface soil moisture favored the seeding and perpetuation of Dallisgrass regardless of land preparation. Only a few plants were found where the topsoil was dry for extended periods.

Level of fertility evidently was also a limiting factor and scarcely met growth requirements for good stands of Dallisgrass. Even where good stands of Dallisgrass were originally obtained, the plants diminished rapidly after 1 or 2 years. Decline was hastened by rapidly invading carpetgrass, which was definitely favored by the fertility level and intensity of grazing.

Dallisgrass, being very palatable, was grazed close and when available contributed proportionately large amounts to cattle diet. Amount consumed by cattle was in direct proportion to coverage. During the year when Dallisgrass was most prevalent, it provided substantial cattle feed; by 1954 it was a minor constituent of cattle diet.

Big Trefoil

This legume was successfully introduced into all range units. Seedling establishment and survival on undisturbed soil equaled that where sod was disked or cut and native vegetation wholly or partially eliminated (fig. 3). The most important factor favoring the seedlings was soil moisture. Excellent stands were obtained in the lower portions of each unit, where surface soil was generally moist, but there were fewer plants on the upper, drier areas.

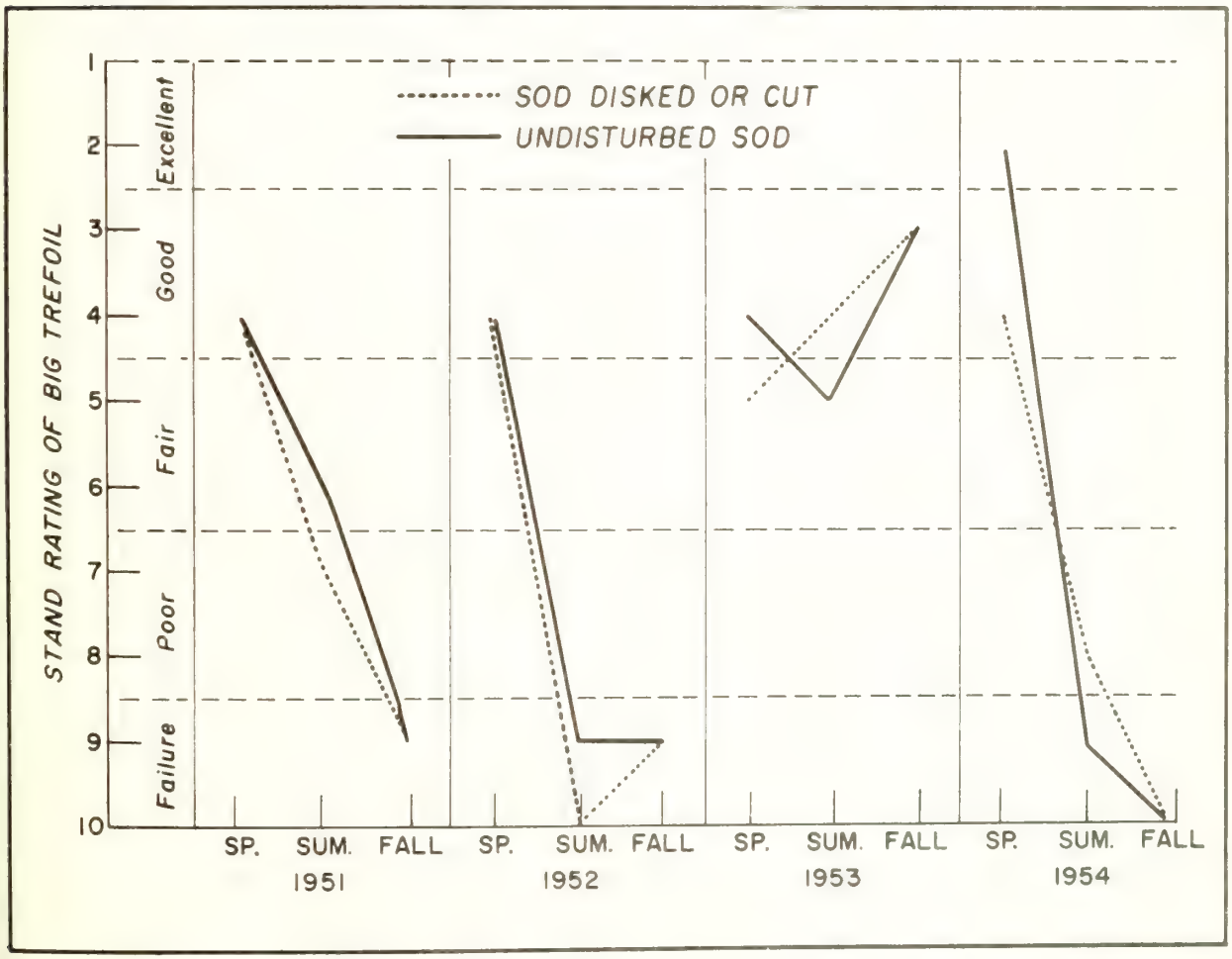

Figure 3.--Big trefoil was readily established and made good growth during the spring. Hot dry weather and disease practically eliminated top growth. With good soil moisture, many plants persisted and made excellent growth during the summer.

Following initial establishment, however, big trefoil had an erratic, seasonal production dependent upon temperature, soil moisture, and incidence of disease and insects. In 1951, this plant made good spring and summer growth. Dry weather and severe attacks of disease and insects in August and September destroyed the top growth of nearly all plants.

Plants were particularly susceptible to black patch fungus and the summer blight caused by Rhizoctonia solani. Lesser damage was caused by the fungus Sclerotium rolfsii and the leafspot Cercospora loti. Many plants were severely damaged or killed by the three cornered alfalfa hopper (Spissistilus festinus).

Destruction of top growth was permanent for plants on the drier sites, but roots survived in moist areas and many plants recovered during late fall. In December, the drier sites were reseeded. Recovery of old plants on moist sites and establishment of new seedlings on the drier sites afforded good stands by the spring of 1952. Disease again became prevalent early in the season, and by July top growth of most plants had been destroyed. The younger, more recently seeded trefoil was least affected. Favorable rainfall during August permitted a good many plants to recover.

Fair to good stands of big trefoil prevailed in the spring of 1953. Above normal precipitation provided favorable soil moisture conditions for abundant growth. Disease and insects were prevalent and much topgrowth was destroyed but enough plants recovered to furnish fair to good stands throughout the summer. Heavy precipitation in September accompanied by a lessening of disease brought forth abundant growth so that stand ratings in October were superior to those at any other time during the year.

These good to excellent stands carried through the spring of 1954. Disease was prevalent by May and greatly increased by the latter part of June. Extremely hot dry weather persisted throughout the summer and fall. By late July, about 90 percent of big trefoil plants appeared dead. Observations in late October showed no evidence of recovery.

Big trefoil was very palatable and supplied a good portion of livestock feed. When abundant and in a healthy growing condition it contributed more feed than any other single species. The tendency for it to die back during late summer and early fall made it undependable as a source of feed. With reseeding, it may offer a valuable source of feed during spring and early summer, especially on moist sites.

Carpetgrass

Seedings of carpetgrass were not successful on undisturbed sods the first year because native bunchgrasses were not grazed close enough (fig. 4). These units were burned again in January 1951, seeded in the early spring, and grazed closely by heifers during the summer. In 1952, good stands of carpetgrass were present and in 1953 it covered most areas continually and closely grazed. In portions of the units where grazing had been light, the native bunchgrasses were not eliminated, and carpetgrass did not take over.

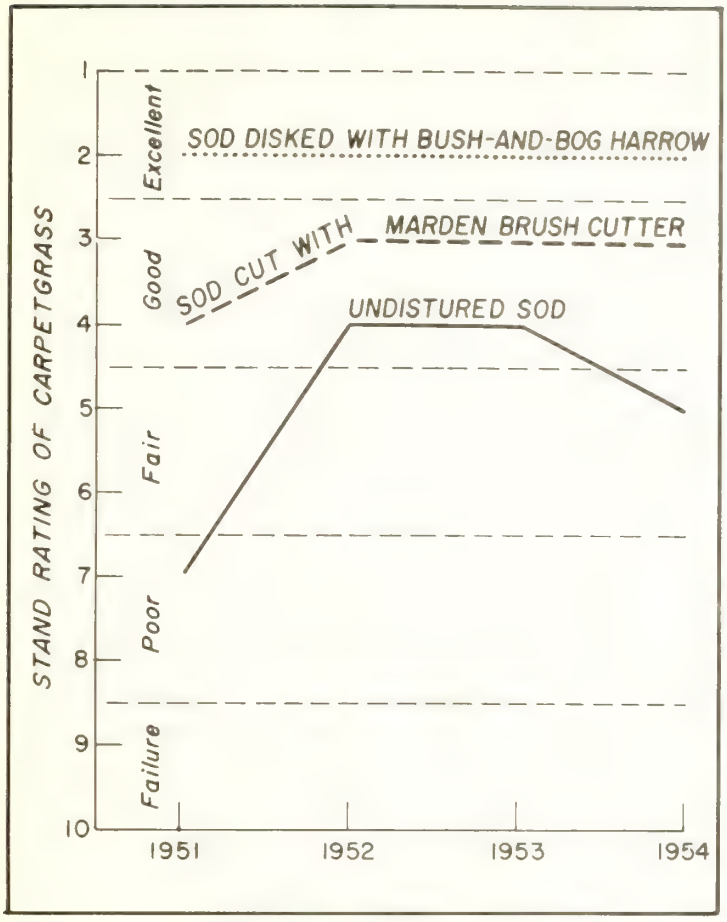

Figure 4.--Carpetgrass establishment was dependent upon land preparation or removal of native grasses by grazing.

Where some form of seedbed was prepared, carpetgrass readily became established (fig. 5). Coverage was in proportion to exposure of mineral soil and elimination of native grasses. Practically a complete cover was obtained on areas effectively treated by bush-and-bog harrow or Marden brush cutter. Where native sod was not destroyed, the invasion of carpetgrass was dependent upon the elimination of native vegetation by grazing.

Cattle grazed carpetgrass very closely. When abundant, this species contributed the greater portion of feed during the late spring, summer, and fall. Other than in early spring immediately after a burn, animals definitely preferred this species to native bunchgrasses. In 1953, carpetgrass contributed less to cattle diet than in 1952 and 1954, but this was due to the abundance of common lespedeza. On the other hand, carpetgrass contributed a proportionately large amount of feed in 1954 because growth and production of lespedeza was considerably less than in the previous year.

Common Lespedeza

Seeding of common lespedeza on undisturbed sod immediately following a burn provided very good stands (fig. 6). Even though this annual plant was grazed closely, enough seed were produced each year to perpetuate good stands through 1953. A noticeable reduction occurred during 1954, probably because of severe drought and very close grazing.

Figure 5.--Good stands of carpetgrass were readily established with little fertilization where land was broken.

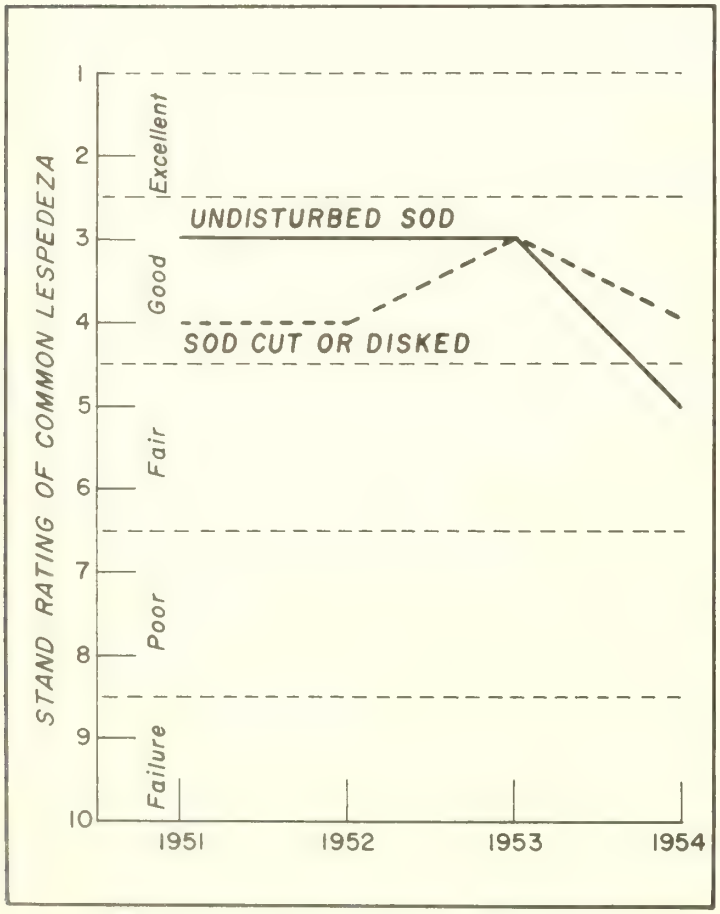

Figure 6.--Good stands of common lespedeza were readily established and maintained, although decreases were noted during the drought of 1954.

Land preparation was not beneficial to the seeding of lespedeza. In fact, stands generally were poorer on the disturbed sods. No difference was discernible between areas gone over with bush-and-bog harrow or brush cutter. Good stands were extended through 1954, though plants diminished slightly during the drought of 1954.

Lespedeza was eatenly readily by cattle and, depending upon its abundance in relation to other species, contributed a good share of the cattle feed. In the summer of 1951 it furnished the greater portion of feed where sod was undisturbed and carpetgrass was scarce. However, on units where sod was disked or cut and carpetgrass was plentiful, lespedeza production was considerably less. The trend in use of lespedeza was similar on all units after 1951: it was very productive in the spring and early summer but contributed little during October, although in 1953 production held up well through the entire season; in 1954, even though stands were reduced and growth was curtailed, the plants furnished feed throughout the season.

EFFECT OF LAND PREPARATION AND FERTILIZATION ON NATIVE VEGETATION

Grasses

Native grasses comprised the greater portion of herbaceous vegetation at the beginning of the study in 1949. The degree and rapidity with which these species were eliminated the next few years depended upon the type of land preparation (table 1).

On units where sod was undisturbed, grazing tended to eliminate all grasses other than the sod-forming carpetgrass which had previously invaded localized areas. Light grazing the first year had a spotty effect on pineland threeawn, but repeat burning and close grazing later on diminished this plant on all units. Without burning, it subsequently became unpalatable and thus increased in ground cover the next few years. Grazing effects on Curtiss dropseed, trinius threeawn, and miscellaneous grasses were not pronounced the first 2 years, but extended grazing thereafter caused the plants to be less prevalent. Bluestems, fairly stable the first 2 years, were reduced to less than one-third of their original ground cover by 1954.

Carpetgrass, of course, was seeded on units fertilized at a low rate, and the plant increased quite rapidly. However, it was not seeded on moderately fertilized units, where it was regarded as an undesirable species. Even though carpetgrass was regarded as a tame forage plant, it was originally present and with heavy grazing it increased very rapidly. Under conditions of this experiment, carpetgrass increased almost as rapidly on unseeded as on undisturbed seeded units.

Sod cutting with a Marden brush cutter reduced native species by approximately one-half. Continued grazing did not reduce the cover of pineland threeawn, but other bunch grasses tended to decrease. Carpetgrass, although not seeded on moderate fertility units, increased at about the same rate and

Table 1.--Changes in ground cover of native grasses under three types of land preparation, two levels of fertilization, and grazing, 1949-1954
(In percent of ground cover)

Species	Level of fertilization	1949	1950	1951	1954
UNDISTURBED SOD					
Pineland threeawn	Moderate	4.7	4.8	1.9	3.8
	Low	4.3	3.3	1.6	3.5
Curtiss dropseed	Moderate	.7	.3	.6	.1
	Low	.3	.4	.5	.1
Bluestems	Moderate	3.8	2.1	3.7	1.1
	Low	4.3	2.4	3.1	1.2
Trinius threeawn	Moderate	1.3	.8	.8	.3
	Low	1.5	.9	1.5	.3
Carpetgrass	Moderate	3.2	3.9	11.2	16.9
	Low	4.7	9.3	11.6	23.0
Miscellaneous grasses	Moderate	3.1	2.9	2.8	2.6
	Low	3.9	2.0	1.0	.8
SOD CUT WITH MARDEN BRUSH CUTTER					
Pineland threeawn	Moderate	3.5	1.8	1.7	2.0
	Low	2.5	1.8	1.4	1.1
Curtiss dropseed	Moderate	1.0	(1/)	.1	(1/)
	Low	.7	.4	1.1	.4
Bluestems	Moderate	3.4	1.3	3.0	.6
	Low	4.0	1.2	1.3	.5
Trinius threeawn	Moderate	1.5	1.1	.6	.3
	Low	2.1	1.1	.8	.4
Carpetgrass	Moderate	3.6	6.3	9.7	17.2
	Low	1.6	6.4	10.1	44.5
Miscellaneous grasses	Moderate	4.6	2.6	1.0	.2
	Low	3.1	2.1	1.6	1.2
SOD DISKED WITH BUSH AND BOG HARROW					
Pineland threeawn	Moderate	3.5	.1	.1	.1
	Low	2.5	.2	(1/)	.5
Curtiss dropseed	Moderate	1.0	(1/)	.1	(1/)
	Low	.7	.1	.1	.2
Bluestems	Moderate	3.4	.2	.6	.3
	Low	4.0	.1	.3	.4
Trinius threeawn	Moderate	1.5	1.0	1.7	.3
	Low	2.1	.9	1.3	.2
Carpetgrass	Moderate	3.6	6.1	7.9	23.7
	Low	1.6	15.8	46.0	50.0
Miscellaneous grasses	Moderate	4.6	4.0	2.1	1.0
	Low	3.1	3.2	1.4	.9

1/ Less than 0.05 percent.

extent as previously noted on the undisturbed sod. However, the Marden brush cutter sufficiently exposed mineral soil so that carpetgrass gained a foothold much more rapidly on the low fertility units seeded to this species.

The bush-and-bog harrow practically eliminated pineland threeawn, Curtiss dropseed, and the bluestems. The decline was less abrupt for trinius threeawn and miscellaneous species, but continued grazing reduced the latter considerably by 1954. This large reduction in native species enabled carpetgrass to attain a greater coverage than was noted on any other units.

Broad-leaved Herbs

A combination of land preparation and fertilization affected the degree of invasion or change in ground cover of broad-leaved herbs. The two species which did not show a decrease on undisturbed soils were hairy trilisa and grassleaf goldaster. The latter was the only species to enhance its position on units fertilized at a low rate. Although other herbs tended to increase the first year, grazing and competition from native and tame grasses reduced them to negligible amounts by 1954 (table 2).

Where the sod was broken, hairy trilisa and grassleaf goldaster were greatly reduced. Other weeds did not become a serious problem with low fertilization, but on the moderately fertilized units several tall-growing weeds invaded and became rather prominent by 1954 (fig. 7). Dogfennel, originally present in small amounts,increased considerably and became the most prominent herb under moderate fertilization where the sod was broken. Otherwise, its occurrence was of minor importance. Other unpalatable species which invaded or increased were goldenrod, camphor weed, and fleabane.

Figure 7.--Left, very few weeds and shrubs remained stable on undisturbed soils where fertilization rate was low. Right, dogfennel and blackberry invaded where sod was broken and fertilization rate was moderate.

Table 2.--Change in ground cover of broad-leaved herbs under three types of land preparation, two levels of fertilization, and grazing, 1949-1954
(In percent of ground cover)

Species	Level of fertilization	1949	1950	1951	1954
UNDISTURBED SOD					
Grassleaf goldaster	Moderate	0.8	1.3	1.5	0.2
	Low	1.2	1.4	3.3	2.9
Hairy trilisa	Moderate	.5	.8	.2	.9
	Low	.4	.6	.3	.4
Dogfennel	Moderate	--	.2	.1	(1/)
	Low	.1	.2	.1	(1/)
Goldenrod	Moderate	--	--	--	.1
	Low	--	--	--	--
Miscellaneous	Moderate	2.4	3.7	1.0	.5
	Low	1.6	2.5	1.3	.4
SOD CUT WITH MARDEN BRUSH CUTTER					
Grassleaf goldaster	Moderate	1.8	0.5	0.6	--
	Low	.9	.7	.5	0.3
Hairy trilisa	Moderate	.7	.8	.2	.4
	Low	.8	.7	.4	.2
Dogfennel	Moderate	.1	.2	.1	4.3
	Low	.1	.2	(1/)	(1/)
Goldenrod	Moderate	--	--	--	.5
	Low	--	--	--	--
Miscellaneous	Moderate	2.8	2.5	.8	1.2
	Low	1.7	2.4	.4	.2
SOD DISKED WITH BUSH AND BOG HARROW					
Grassleaf goldaster	Moderate	1.8	.2	(1/)	--
	Low	.9	(1/)	(1/)	0.1
Hairy trilisa	Moderate	.7	.4	(1/)	.2
	Low	.8	.5	.2	.3
Dogfennel	Moderate	.1	.3	.3	3.0
	Low	.1	.2	--	--
Goldenrod	Moderate	--	--	--	1.1
	Low	--	--	--	--
Miscellaneous	Moderate	2.8	2.6	1.9	.4
	Low	1.7	2.6	.5	.5

1/ Less than 0.05 percent.

Shrubs

Gallberry, sawpalmetto, and staggerbush remained quite stable where sod was undisturbed (table 3). A moderate rate of fertilization caused runner oak and blackberry to increase. The latter, a troublesome thorny shrub, spread greatly and by 1954 comprised approximately 43 percent of the total shrub cover (fig. 8). It was noticeably more dense on moist areas, where it often formed impenetrable thickets and restricted herbaceous growth and livestock grazing.

Figure 8.--Dense thickets of blackberry invaded low moist areas where fertilization rate was moderate.

The Marden brush cutter was of little value in eliminating shrubs. Most all species other than sawpalmetto have extensive underground rootstocks which enabled them to survive the cutting effects of this equipment. The bush-and-bog harrow, however, cut and exposed the rootstocks sufficiently to kill a good many plants (fig. 9). Shrubs that survived the original treatment persisted but spread little during the rest of the study. Blackberry, again an exception, continued to increase on units fertilized at a moderate rate, particularly where soil moisture conditions were favorable.

Table 3.--Change in ground cover of shrubs under three types of land preparation, two levels of fertilization, and grazing, 1949-1954
(In percent of ground cover)

Species	Level of fertilization	1949	1950	1951	1954
UNDISTURBED SOD					
Gallberry	Moderate	4.4	4.1	5.3	3.9
	Low	4.0	4.1	4.1	4.2
Runner oak	Moderate	.8	.6	1.4	1.7
	Low	.3	.5	.1	.4
Blackberry	Moderate	.2	.3	.8	5.8
	Low	.5	.6	.6	.8
Sawpalmetto	Moderate	.6	.8	.2	.4
	Low	.4	.2	.4	.6
Staggerbush	Moderate	.2	.2	.1	.1
	Low	.4	.1	.2	.4
Miscellaneous	Moderate	.5	.7	.9	1.7
	Low	1.2	.9	1.0	2.1
SOD CUT WITH MARDEN BRUSH CUTTER					
Gallberry	Moderate	4.5	2.9	3.2	2.9
	Low	4.2	3.8	5.8	3.4
Runner oak	Moderate	.9	.3	.4	.5
	Low	.8	1.1	.3	.8
Blackberry	Moderate	.2	.8	1.1	5.3
	Low	.2	.2	.4	.4
Sawpalmetto	Moderate	.3	(1/)	.1	(1/)
	Low	.3	.2	.2	--
Staggerbush	Moderate	.2	(1/)	(1/)	(1/)
	Low	.3	(1/)	.1	.2
Miscellaneous	Moderate	1.9	.6	1.2	.3
	Low	.8	.3	.6	.4
SOD DISKED WITH BUSH AND BOG HARROW					
Gallberry	Moderate	4.5	.8	1.3	.8
	Low	4.2	1.2	1.8	1.6
Runner oak	Moderate	.9	.1	.2	.3
	Low	.8	.4	.2	.8
Blackberry	Moderate	.2	.2	1.1	3.3
	Low	.2	.2	(1/)	.1
Sawpalmetto	Moderate	.2	.1	(1/)	(1/)
	Low	.3	.1	.1	--
Staggerbush	Moderate	.2	.1	.1	.1
	Low	.3	(1/)	.2	.1
Miscellaneous	Moderate	1.9	.5	.5	.1
	Low	.8	.3	.4	.3

1/ Less than 0.05 percent

Figure 9.--Upper photo, bush-and-bog harrow destroyed native sod and eliminated most of shrubs on right. Area on left was undisturbed. Lower photo, five years later, very few shrubs or weeds were present on a good carpetgrass sod fertilized at a low rate. Native shrubs had increased in height and blackberry invaded area in left, which had been fertilized at moderate rate.

Pine Tree Reproduction

Neither slash nor longleaf seed trees produced enough seed during 1950 and 1951 to provide for establishment of seedlings. Squirrels ate most of the longleaf seed and prevented establishment of this species. Slash pine cone production increased the third year after seed tree release, as shown below:

Year	Number of cones per slash pine tree
1950	5
1951	8
1952	55
1953	54
1954	49

Slash pine seedling establishment from the 1952 and 1953 seed crops was ascertained by an inventory of sixteen 100-square-foot plots in each unit at the end of the grazing season in 1954 (table 4). As indicated by the percent of plots with live seedlings, establishment was rather sporadic and depended largely upon the number of seed trees. Best stocking was obtained in the series of units 1 through 4, where slash pine seed trees were most prevalent (fig. 10). Poorest stocking was found in units 7 and 8, where there were very few seed trees. With ample seed source, a good number of young slash pine seedlings became established and survived the first year of grazing.

Figure 10.--Young slash pine became established where seed source was ample. Heavy grazing subsequently eliminated many of the seedlings shown here.

Table 4.--Slash pine seedling establishment from natural seed source, 1954

Condition of sod	Level of fertility	Pasture number	Slash pine seed trees per acre	Plots with live seedlings	Seedlings per acre
			Number	Percent	Number
Undisturbed	Moderate	4	7	81	898
"	"	6	4	56	272
"	Low	3	5	44	680
"	"	8	1	19	109
Cut or disked	Moderate	1	8	81	980
" " "	"	7	3	31	163
" " "	Low	2	7	75	1,280
" " "	"	5	3	44	572

Heavily concentrated grazing killed many young seedlings. Natural seedfall was augmented by scattering 500 slash pine seed per plot in January of 1953. Average numbers of seedlings on grazed and ungrazed plots at the beginning and end of the grazing season were as follows:

Month and year	Grazed	Ungrazed
April 1953	26	36
October 1953	19	38
April 1954	24	57
October 1954	13	37

Since cattle had access to grazed plots approximately one month before seedling counts were made in April 1953, differences in number of seedlings at that time were perhaps attributable to grazing by cattle. Grazing continued to destroy seedlings from April to October. There was a 27-percent decline in numbers on grazed plots, whereas seedling numbers were maintained on ungrazed plots.

Natural seedfall during the winter of 1953-1954 distributed additional seed on these plots and contributed seedlings from 1953 to the spring of 1954. Heavy mortality of seedlings took place during the hot dry summer and fall of 1954. Seedling numbers were reduced on all plots, but the least reduction occurred on ungrazed plots. By October 1954, the ungrazed plots had nearly 3 times as many 1- and 2-year-old slash pine seedlings as the grazed plots.

CATTLE PERFORMANCE AND ECONOMIC RETURNS

Cattle Weights as Influenced by Forage Species

Quantitative evaluation of pasture production was based on allowable animal days of grazing, total animal gains per acre, and conversion of animal weights and gains to total digestible nutrients per acre. Quality of pasture herbage was measured by daily gain per animal (table 5 and fig. 11).

Figure 11.--Representative group of heifers used for evaluating range improvement practices.

Table 5.--Forage production and animal performance, by forage species, treatment, and years

Year	Unit of measure	Carpetgrass-common lespedeza		Dallisgrass-big trefoil	
		Sod cut or disked	Undisturbed sod	Sod cut or disked	Undisturbed sod
1951	Total	572	712	1,148	1,081
1952	digestible	441	566	892	822
1953	nutrients in	507	483	666	754
1954	pounds per acre	324	313	692	1,002
Average		461	519	850	916
1951	Allowable	98.0	98.0	147.0	147.0
1952	animal days	70.0	81.7	122.5	119.0
1953	per acre	77.0	74.7	101.5	115.5
1954		60.7	60.7	105.0	129.5
Average		76.4	78.8	119.0	127.8
1951	Total gain	53.8	110.5	178.7	141.6
1952	in pounds	68.3	90.2	143.8	135.0
1953	per acre	71.0	68.5	91.3	102.0
1954		12.7	25.9	90.5	104.5
Average		51.5	73.5	127.3	120.8
1951	Daily gain	.55	1.13	1.21	.97
1952	in pounds	.87	1.10	1.16	1.15
1953	per animal	.93	.90	.90	.88
1954		.21	.43	.92	.80
Average		.66	.89	1.05	.95

Animal performance data indicated quite clearly that range improvement practices had a noticeable effect on quantity of forage produced. Significant differences were observed during most years for all the measures of per-acre production of forage between the relatively low-fertility carpetgrass-lespedeza units and the moderate-fertility Dallisgrass-big trefoil units.

The initial land preparation had little over-all effect on the per-acre measures of forage production. In no case was the yield of beef from harrowed, disked, or cut units significantly different from that on undisturbed units. However, certain relationships existed between beef production and abundance of seeded plants. For instance, on the Dallisgrass-big trefoil pastures which had land preparation, per-acre gains tended to be greater during 1951 and 1952. Since big trefoil stands were very similar, the difference was probably due to better Dallisgrass stands during these years. Conversely, cattle gains were better the following 2 years, 1953 and 1954, on units without land preparation. During this time Dallisgrass stands had become similar between units, but the greater gains can be attributed to the better stands of big trefoil present during spring months.

Forage quality as measured by average daily gain per animal was significantly affected by neither species composition nor fertilizer level. But here again, certain similarities were apparent. Daily animal gains were closely associated with the stands of Dallisgrass. On disked or cut units, both Dallisgrass stands and daily gains per animal were best in 1951. When Dallisgrass became less prevalent the following years, daily gains dropped perceptibly. On units without land preparation, daily gains were also best during the year that Dallisgrass was most prevalent. From 1952-1954, daily gains per animal and Dallisgrass stands were both slightly better on units with land preparation.

Similar relationships were evident in the carpetgrass-lespedeza units. Where land had been disked or cut and native grasses practically eliminated, only a limited amount of forage was available during the spring of 1951. Per-acre and per-animal gains were relatively poor. However, units without land preparation but burned the previous winter possessed an abundant native forage. This, in addition to good stands of lespedeza enabled animals to make better gains in 1951 and 1952.

Daily gains per animal were similar in all units in 1953, signifying forage quality was approximately the same--the reason being that carpetgrass had become the main grass in all units. The daily gains in carpetgrass-lespedeza units in 1954 were low because extremely dry weather severely reduced forage production. Moderately fertilized pastures were more productive, ample forage was available, and animals made daily gains comparable to the previous year.

Financial Return in Terms of Beef Production

A tabulation of costs and returns indicates that none of the treatments yielded large returns of salable beef. Broadcasting carpetgrass and lespedeza on undisturbed forest soils and applying fertilizer at a low rate was the most economical practice (table 6). Returns based on current price of beef were nearly four dollars per acre per year. Net returns could possibly be increased by eliminating the cost of seeding carpetgrass and permitting this grass to become established naturally.

Table 6.--Average costs for range revegetation practices, and returns from grazing cattle, 1951-1954
(In dollars per acre)

Item	Carpetgrass-common lespedeza		Dallisgrass-big trefoil	
	Land disked or cut	No land preparation	Land disked or cut	No land preparation
Cost				
Seedbed preparation	5.60	0.0	5.60	0.0
Fertilizer	19.00	19.00	38.00	38.00
Lime	0.0	0.0	6.80	6.80
Seed	3.60	3.60	10.50	10.50
Labor	4.00	4.00	4.00	4.00
Total	32.20	26.60	64.90	59.30
Return				
Gross from beef at $0.15 per pound	30.25	42.00	74.97	72.84
Net	1.95	15.40	10.07	13.54

In terms of beef production, land preparation did not pay. Under both moderate and low level rate of fertilization, net returns were greater on land that was undisturbed. Also, weeds were less troublesome on undisturbed soils.

SUMMARY

Range improvement practices were evaluated from 1949 through 1954 for a longleaf-slash pine forest clearcut to seed trees. Carpetgrass and common lespedeza were broadcast seeded on undisturbed soils, and on soils chopped or disked. They were compared with seedings of Dallisgrass and big trefoil on undisturbed, chopped, and disked soils. Annual fertilization was at the rate of 30 pounds per acre of phosphate and 30 pounds of potash on the carpetgrass-lespedeza units and 60 pounds each on the Dallisgrass-big trefoil units.

Treatments were evaluated through response of seeded and native plants, pine seedling survival, and animal performance.

Where native vegetation was destroyed and mineral soil exposed, successful stands of Dallisgrass were established; seedings were unsuccessful on burned undisturbed sod. Under conditions of this experiment, Dallisgrass was crowded out by native carpetgrass in a very few years.

Big trefoil readily became established with or without land preparation. Establishment and survival were dependent to a great extent on moisture. The limiting factor in perpetuating this plant was the prevalence of several insects and diseases which attacked it severely during the summer. The plant was better able to withstand and recuperate from disease when soil moisture was ample. It furnished valuable forage during spring and summer when moisture was sufficient and disease not too severe.

Carpetgrass became the most abundant and important grass for grazing on all ranges regardless of land preparation or seeding treatment. Land preparation did, however, speed up establishment and permit better stands to be maintained.

Seeding of common lespedeza on undisturbed sod, immediately following a burn, provided very good stands. Land preparation did not benefit this species. Lespedeza produced enough seed annually to perpetuate itself, but a severe drought and extremely close grazing thinned out the stand in 1954.

Native grasses responded directly to grazing and land preparation. Bunchgrasses and single stem species decreased with grazing. Land preparation tended to eliminate these species. The sod-forming carpetgrass increased with grazing, particularly where the sod had been broken.

Broad-leaved herbs such as dogfennel and goldenrod became troublesome where sod was broken and pastures moderately fertilized. Grassleaf goldaster increased with grazing on undisturbed soils fertilized at low rate.

Shrubs remained quite stable on undisturbed sods where the fertilization rate was low. The brush cutter was less effective than the bush-and-bog harrow in eliminating shrubs. Blackberry increased greatly on ranges moderately fertilized. It became particularly dense and formed impenetrable thickets where soil was moist.

Slash pine seed production increased the third year after seed tree release. Survival of slash pine seedlings 2 years later was sporadic and incomplete. Grazing destroyed many 1- and 2-year-old seedlings. Adequate pine tree reproduction would be dependent upon more seed trees or a reduction in grazing intensity for 1 or more years following seed dispersal. Longleaf pine seed were nearly all consumed by squirrels.

Animal performance data in TDN production, total animal weight gain, and length of grazing season indicated that fertilization rate had a significant effect on forage production. Forage quality, as indicated by daily weight gain, was closely related to the abundance of seeded forage species such as Dallisgrass.

Economic returns from these trial practices in terms of beef production indicate that initial land preparation did not pay. Seeding of tame forage species on undisturbed sod was more economical. Carpetgrass and common lespedeza on these infertile soils afforded the greatest net return.

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APPENDIX

Table 7.--Monthly precipitation records at Alapaha, Georgia, 1950-1954
(In inches of rainfall)

Month	1950	1951	1952	1953	1954
January	.87	1.31	1.99	3.49	1.33
February	1.30	2.10	4.51	5.79	1.12
March	7.70	8.61	3.35	2.45	1.84
April	2.30	2.63	2.23	4.90	3.38
May	3.48	2.38	3.92	3.26	3.69
June	2.17	3.18	.82	4.66	2.88
July	8.80	5.62	3.75	7.92	1.40
August	5.01	2.89	6.50	7.05	3.18
September	2.16	5.54	5.33	10.21	2.34
October	3.83	.91	1.56	.67	.47
November	2.14	3.85	1.33	.90	1.86
December	3.80	5.57	2.29	8.52	2.99
Total	43.56	44.59	37.58	59.82	26.49

Table 8.--Partial list of plants found on experimental site

Common name	Scientific name
TAME FORAGE PLANTS	
Dallisgrass	Paspalum dilatatum Poir.
Big trefoil	Lotus uliginosus Schkuhr.
Carpetgrass	Axonopus affinis Chase
Common lespedeza	Lespedeza striata (Thunb.) H. and A.
NATIVE GRASSES	
Pineland threeawn	Aristida stricta Michx.
Curtiss dropseed	Sporobolus curtissii (Vasey) Small ex Scribn.
Panicum	Panicum spp. L.
Bluestems	Andropogon spp. L.
Trinius threeawn	Aristida affinis (Schult.) Kunth.
BROAD-LEAVED HERBS	
Grassleaf goldaster	Chrysopsis graminifolia (Michx.) Nutt.
Hairy trilisa	Trilisa paniculata (Walt.) Cass.
Goldenrod	Solidago microcephella (Greene) Bush
Dogfennel	Eupatorium compositifolium Walt.
Camphorweed	Heterotheca subaxillaris (Lam.) Britt and Rusby
Fleabane	Erigeron pusillus Nutt.
SHRUBS	
Gallberry	Ilex glabra (L.) A. Gray
Runner oak	Quercus pumila Walt.
Blackberry	Rubus cuneifolius Pursh
Sawpalmetto	Serenoa repens (Bartr.) Small
Staggerbush	Xolisma fruticosa (Michx.) Nash

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Cost of Operation for Three Types of Charcoal Kilns

by Boyd M. Witherow

and Walton R. Smith

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

Joseph F. Pechanec,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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COST OF OPERATION FOR THREE TYPES OF CHARCOAL KILNS

by

Boyd M. Witherow and Walton R. Smith
Division of Forest Utilization Research

INTRODUCTION AND SUMMARY

The current upswing in use of charcoal for backyard cooking, picnics, and barbecuing creates a large domestic market, especially during the warm-weather months. This increased demand is not being met by present producers, and so there is widespread interest in "getting into the charcoal business."

A considerable volume of charcoal is produced in rather inexpensive kilns of sheet metal or masonry block. Because of the increasing demand for information about the relative merits of such kilns, their operating procedures, charcoal yields, and operating costs, the U. S. Forest Service, in cooperation with the North Carolina Department of Conservation and Development, North Carolina Forest Service, conducted a charcoal-kiln study at the Bladen Lakes State Forest near Elizabethtown, North Carolina. Four kilns were used in the study. Two were $\frac{1}{2}$-cord sheet metal units (fig. 1), one was a $1\frac{1}{2}$-cord sheet metal unit (fig. 2), and the fourth a double-wall masonry block structure of 2-cord capacity (fig. 3).

Of the three types studied, the 2-cord cinder block kiln produced the highest yields and had the lowest depreciation cost. It was, for these reasons, the most profitable to operate, though labor cost during burning and cooling periods was higher. On a basis of present-day prices for wholesale charcoal, none of the kilns studied showed a safe margin of profit. Opportunities to increase the profit margin lie in mechanizing the handling of wood and charcoal, operating batteries instead of single kilns, obtaining cheaper wood, and using larger kilns.

METAL KILNS

Two of the metal kilns were standard $\frac{1}{2}$-cord units purchased by the North Carolina Forest Service from a commercial fabricator in Georgia. These kilns are readily portable, having two circular sections and a separate, coned lid. The bottom section is 14-gage sheet metal and the upper section and lid are 16-gage metal. The two sections and the lid give the kiln a total height of 5 feet 6 inches. The diameter of the base is 7 feet, while the top section and lid diameter is 4 feet 6 inches, which gives the assembled kiln its truncated cone shape. All sections are flanged to stiffen the shell. These

Figure 1.--One-half-cord sheet metal kiln, fully assembled and in the coaling phase.
Photo by N. C. Dept. of Conservation & Development

Figure 2.--Bottom section of $1\frac{1}{2}$-cord metal kiln being charged with wood. Note joint where sections are bolted to form the complete bottom ring.

Figure 3.--Two-cord double-wall masonry block kiln. Note propped metal door and independently supported roof.

flanges fit snugly into gutters welded to the upper side of the section beneath (fig. 4). The lid has a short smoke pipe in the center. There are nine 4-inch holes evenly spaced around the base of the bottom section, serving alternately as air inlets and as hot gas outlets. Five-foot cast iron pipes inserted in three of these holes serve as chimneys.

Figure 4.--Bottom half of $\frac{1}{2}$-cord kiln ready for top section. Note gutter for snug fit of top section. In left background, $1\frac{1}{2}$-cord kiln with kindling in place.

The similarly constructed $1\frac{1}{2}$-cord kiln [1/] is made entirely of 16-gage steel. It has a base diameter of 10 feet, a top section and lid diameter of 8 feet, and a total height of 7 feet. Due to its increased size and weight, the two kiln sections are each made up of three smaller sections bolted together to form the complete circle (fig. 2). When completely disassembled, the kiln can easily be transported. The lid has a short 6-inch smoke pipe at its center. The bottom section contains fifteen 4-inch by 4-inch holes which serve as air inlets and hot gas outlets. Eight 10-foot smoke pipes are used with this kiln.

MASONRY BLOCK KILN

The masonry block kiln was an experimental unit designed by the Forest Products Laboratory, but built and operated by the North Carolina Forest Service. It is a double-wall structure employing a propped metal door and an externally supported metal ceiling covered with 3 inches of sand.

1/ Supplied on loan by the Western Carolina Charcoal and Chemical Company, Asheville, N. C.

The entire unit is protected by a wood roof on independent supports. Standard masonry blocks were used throughout, with an 8-inch sand fill between the two walls. Two 8-inch by 8-inch vent ports are located in the ceiling 10 inches behind the door. An 8-inch diameter metal chimney extends from its base at the bottom center of the rear wall to a point 36 inches above the ridge of the roof. The chimney base also contains an 8-inch port where a fire may be built to induce draft in the chimney. The sheet metal door is fitted with angle-iron lugs that serve as stops for the supports used in holding it against the kiln during operation. A coaling chamber 10 feet long, 5 feet 4 inches wide, and 6 feet 8 inches high gives capacity for 2 cords of wood.

WOOD USED

Hardwoods were used exclusively in this study. The bulk came from the red oak group, primarily water (Quercus nigra), southern red (Quercus falcata), and blackjack (Quercus marilandica). The wood, air seasoned approximately 4 months, had reached an average moisture content of 45 percent. Decay was found in the sapwood of much of this material. All wood used was in 4-foot lenghts, both with and without bark (fig. 5).

Figure 5.--Type of wood used as raw material in this study.

The average moisture content was obtained by use of a moisture meter and the ovendry method. Sample sticks were selected at random as the charge was being loaded into the kiln. These sticks were cut in half and a 1-inch moisture content section was sawn from one of the inner faces. A moisture meter reading was then taken on the stick adjacent to the point where the section was removed.

The moisture meter readings averaged within plus or minus 2 percent of the ovendry sample determinations, so the average of all measurements was determined at 45 percent and was used in all the later calculations.

KILN TEMPERATURE DATA

All of the kilns, except one of the $\frac{1}{2}$-cord kilns, were wired with thermocouples to obtain the necessary temperature data (figures 6 through 14). The masonry block kiln was operated to hold the maximum temperature to about 950° F., but the metal kilns were permitted to burn at any temperature reached, as is common in commercial practice. A potentiometer and a microameter 2/ calibrated to degrees Fahrenheit for direct reading were used to indicate the temperatures. Time-temperature graphs were made from the recorded data for all but the two runs conducted in the unwired kiln (figures 8 through 14).

THERMOCOUPLE LOCATION

Three thermocouples were placed along the center line of the masonry block kiln at various heights above the floor. No. 1, located at the front, was at midheight; No. 2, in the center, was 18 inches from the ceiling; No. 3, at the back, was 18 inches from the floor (figures 6, 13, and 14).

The number of thermocouples and their positions were arbitrarily picked for the metal kilns. They were located where it was assumed that temperatures representative of the maximum, minimum, and average conditions within the kilns would be found (fig. 7).

WEIGHT DATA

The weighing procedure was standard throughout the study. All wood was carefully weighed before being placed in the kilns, and records were kept. The bags of charcoal from each kiln were individually weighed, and then totaled for each run.

TIME DATA

All operations were carefully timed. However, this was not a stopwatch procedure in the sense of a standard time-motion study. The time consumed between the beginning and ending of each job, with the number of men working, gave the man-hours required for the job.

2/ Southeastern Forest Experiment Station Paper No. 73, "An Inexpensive Method for Measuring Charcoal Kiln Temperatures," by Ralph Peter, 9 pp., illus. 1956.

Figure 6.--Thermocouple location in the 2-cord masonry block kiln. (No. 1 is tied up here for convenience in working around the front of the kiln. It is lowered when the kiln is loaded.)

Figure 7.--Three thermocouple locations at different elevations were selected for the metal kiln.

FIRING AND COALING METHODS

½-Cord Kiln

The method of ignition and operation for these kilns was the same as that used during the past 2 years of operation on the forest. The lid was placed on the kiln immediately after loading, kerosene was poured through the center smoke pipe, and the charge ignited. Instant firing is necessary after pouring the kerosene so that fumes will not accumulate and cause an explosion when the charge is lit.

Smoke pipes were used in three of the nine holes, thus providing six air inlets. The stacks were put up before the kiln was fired, and they remained in place during the entire burn. They were spaced at equal distances around the base of the kiln.

Approximately 2 hours after ignition, the cap was placed on the central flue. The side smoke pipes promptly gave off a large volume of thick, wet, acrid smoke. Conditions were then favorable for coaling to begin. Later, as each portion of the charge became carbonized, fire appeared at the corresponding air inlet. When careful probing into this opening indicated that no more large unburned sticks remained near the hole, it was covered and banked. This procedure was followed until all draft holes were closed; smoke pipes were then removed and holes covered and banked.

This procedure differs only slightly from that recommended for the Black Rock Forest Kiln.[3/] Normally this type of kiln is ignited with the lid off, permitted to burn freely for 15 or 20 minutes, and then covered.

1½-Cord Kiln

Three burns were made in this kiln during the study. All were ignited in the same manner as that described for the ½-cord kilns, but the operational procedure was changed for the last run.

During the first two burns, the kiln was operated according to the owner's instructions. That is, on one side of the kiln smoke pipes were placed in 8 of the kiln's 15 draft holes, thereby leaving 7 air inlets open on the other side. The kiln was ignited, and after approximately 2 hours it was capped. When coaling progressed to a point where fire appeared at any hole, it was permitted to burn until probing indicated the absence of large unburned sticks in the area of that hole. The adjacent smoke pipe was then moved to the open hole and the vacated hole remained open. If two holes "came in" simultaneously, two stacks were moved. When the smoke from a stack either before or after the first move thinned out considerably and changed to a light blue color, the stack was removed and the hole was covered and banked. If a stack began to "back draft," that is, act as an air inlet, it was removed and the hole was closed.

3/ Black Rock Forest Bulletin No. 4, "A Portable Charcoal Kiln," by Henry H. Tryon, 34 pp., illus. 1933.

The coaling period was considered to be completed when all stacks or the majority of them had been moved from their original locations and all air inlet holes had "come in." Slight probing for the presence or absence of large uncharred sticks also helped to indicate the progress of the burn. The kiln was sealed at the completion of the coaling period by removing all smoke pipes, covering and banking all open holes, and checking for air leaks.

The operational procedure for the third run in this kiln was the same as that used with the $\frac{1}{2}$-cord kilns. Seven smoke pipes were inserted in alternate holes around the base of the kiln and remained stationary during the entire burn. Stacks were removed only if they were "back drafting."

2-Cord Masonry Block Kiln

A predetermined maximum temperature level was the basis for the operational procedure for this kiln during the study. Previous experience with other experimental masonry block kilns indicated that it was important to control temperatures, both from the standpoint of consistent production of quality charcoal and for the prevention of kiln deterioration due to excessive temperatures. The preferred maximum coaling temperature range of 850° to 950° F. was used. Temperature control was obtained by varying the size of the air-intake opening under the kiln door (the only air inlet).

After the kiln had been loaded, a crib of kindling, paper, and brands approximately 4 feet high and 2 feet deep, was built across the front of the charge. The door was put in place and secured with a full air-intake opening under it (3 inches high, extending across the full width of the door opening, thus providing 192 square inches of air-intake space). The port in the base of the chimney was left open, and the ceiling ports were fully opened.

Approximately 2 to 3 gallons of kerosene were poured through the ceiling ports and splashed under the door. Kerosene-soaked newspaper was placed in the opening under the door and ignited. During the succeeding 3 hours, the ceiling ports were progressively closed as the temperatures showed a gradual rise, indicating successful ignition of the charge. The port in the base of the chimney was utilized about 1 hour after firing time, then covered and sealed.

Temperature readings were periodically taken to determine the progress of the burn. Major adjustments of the air-intake space were necessary during the early part of the run to bring the charge to the desired coaling temperature. When this condition had been reached, the adjustment of the air-intake space became very critical, and a minor change had a decided effect on the temperature. Changes, however, became less necessary as the coaling period progressed, and when the temperatures held relatively steady, changes were made only if the allowable maximum was exceeded.

After the lower, rear portion of the charge reached the minimum coaling temperature, the burning time was continued for an average of 6 hours. The air intake port was then closed, but the chimney was left open for approximately 2 hours before the kiln was completely sealed.

RESULTS OF THE STUDY

It must be pointed out that many variables enter into the production of charcoal, and the presence or absence of any one or a combination of several will drastically change the entire picture. This study was not designed nor of sufficient magnitude to include all combinations of these variables. The results presented here represent the man-hour requirements and production costs per ton of charcoal for "a" method of operation. Since an attempt was made to use average conditions, it is felt that these results could be used as a basis for planning a charcoal operation. Local conditions would determine the necessary changes and adjustments.

Charcoal Yield

Acceptable charcoal was produced in all test runs, as indicated in a chemical analysis of several samples removed from each charge (table 1).

Table 1.--Summary of chemical analysis of charcoal from test runs at Bladen Lakes State Forest, December 1956

Kiln type and capacity	Runs	Analysis of charcoal			
		Moisture content	Volatiles	Ash	Fixed carbons
	Number	Percent			
Metal, ½-cord	4	1.77	19.17	1.78	79.05
Metal, 1½-cords	3	1.51	12.37	2.22	85.41
Cinder block, 2-cords	2	2.03	18.27	1.81	79.92

The amount of charcoal produced from a ton of wood (based on ovendry weight of wood) varied considerably by kiln type, being highest for the cinder block kiln and lowest for the 1½-cord metal kiln (table 2). It was expected that the masonry block kiln would produce the highest yield because it was operated under controlled temperature conditions with an attempt to hold the

Table 2.--Summary of wood weight and charcoal yield, on a basis of average per run

Kiln type and capacity	Runs	Wood weight		Brands	Charcoal yield			
		At 45 percent moisture content	Calculated ovendry weight		Lump	Fines	Total	Total based on ovendry wt. of wood
	Number	Pounds						Percent
Metal, ½-cord	4	2842	1959.65	139.25	471.75	61.50	533.25	27.35
Metal, 1½-cords	3	7372	5084.37	492.0	796.67	320.33	1117.00	21.95
Cinder block, 2-cords	2	8101	5586.90	329.50	1505.50	267.00	1772.50	31.72

temperatures under 950° F., and there was also considerably less heat lost through radiation. Lower radiational heat loss results in a smaller amount of the charge being consumed to produce the heat required for carbonization, and this in turn increases the yield. In metal kilns, it was expected that the larger kiln would produce a higher yield than the smaller one, but such was not the case. The larger metal kiln produced an excessive amount of brands, with a yield 5 percent below the ½-cord metal kiln and about 10 percent below the masonry block kiln. This small yield may have been due in part to the inexperience of the operator, who had never worked with a unit of this size.

Temperature Comparisons

There was a wide variation in operating temperatures in the different type kilns and even between different runs of the same kiln, as shown in figures 8 through 14.

It is quite obvious that better coaling conditions (about 900° F.) prevailed for a longer period of time during the coaling phase in the masonry block kiln than in either of the metal kilns. The ½-cord metal unit did not produce as high temperatures as the 1½-cord metal one, which probably accounts for the higher charcoal yield in the smaller metal kiln.

In studying these temperature patterns, it must be remembered that the metal kilns were operated without temperature control, according to usual commercial practice. It might be possible to improve the operation of the metal kilns by attempting temperature control, but that was not an aim of this study.

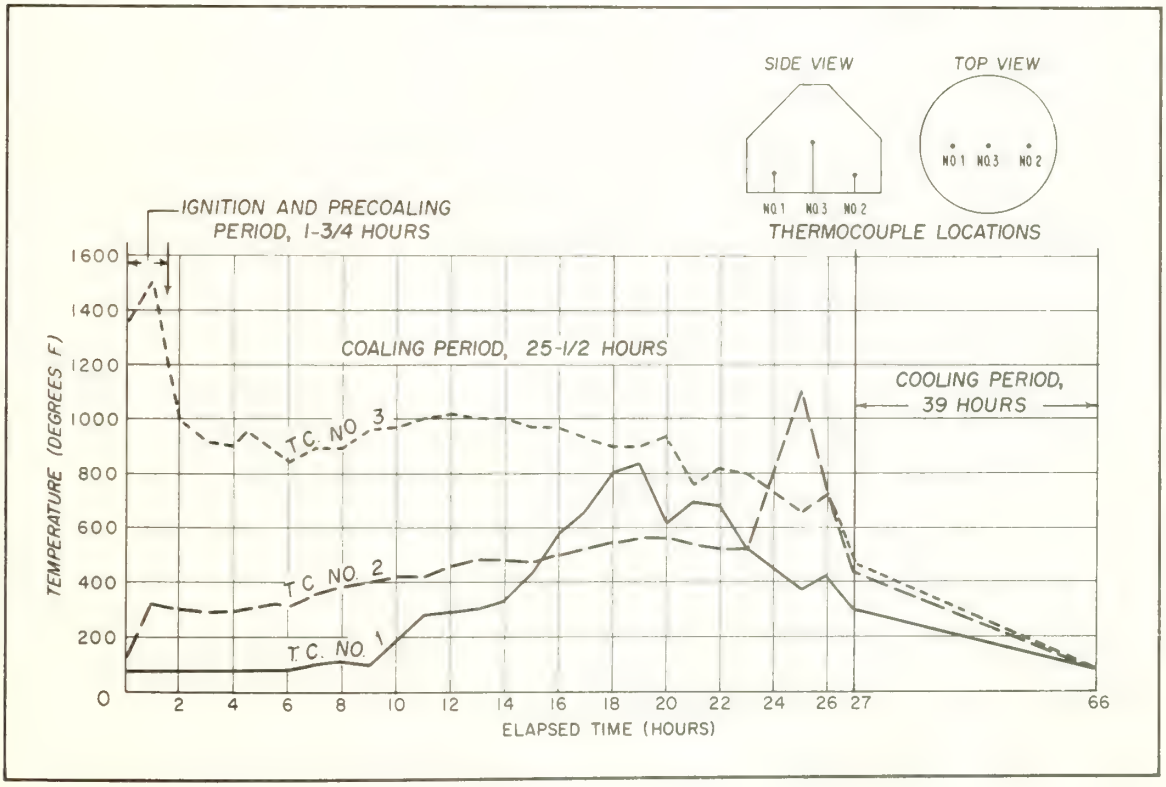

Figure 8.--Temperatures in kiln charge number 1, metal beehive ½-cord kiln.

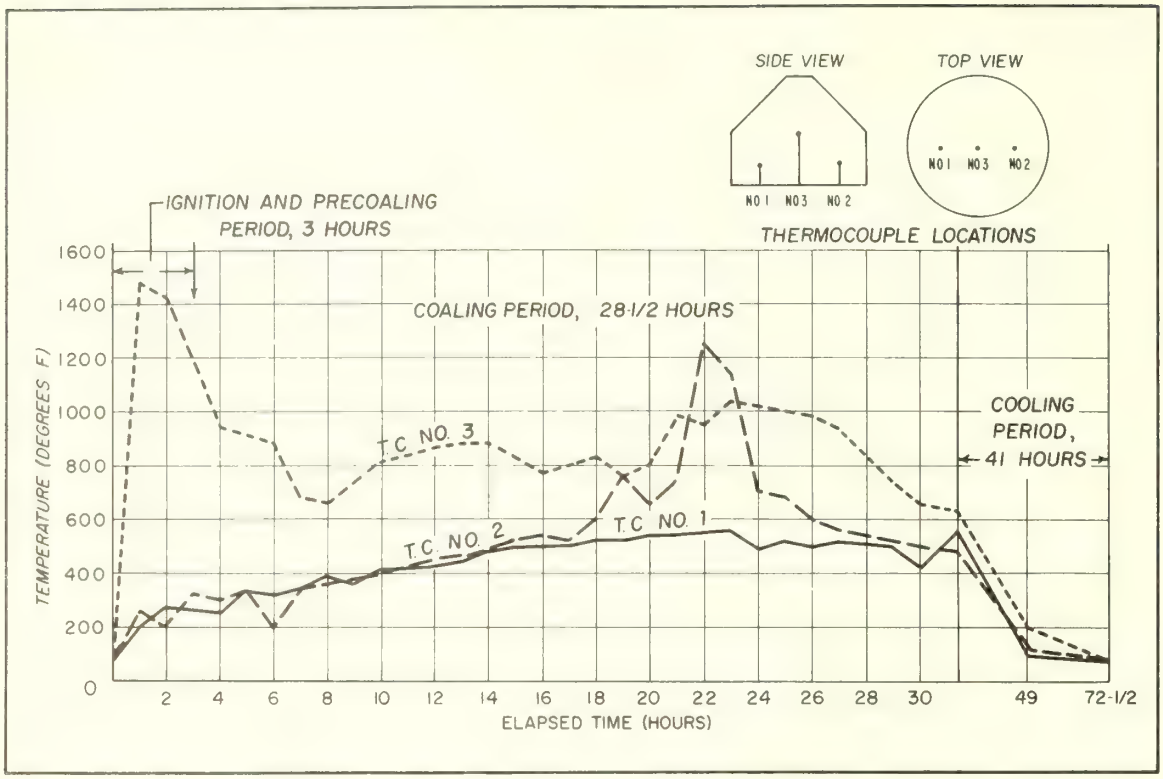
SIDE VIEW
TOP VIEW
NO 1 NO 3 NO 2
NO 1 NO 3 NO 2
IGNITION AND PRECOALING PERIOD, 3 HOURS
THERMOCOUPLE LOCATIONS
COALING PERIOD, 28-1/2 HOURS
COOLING PERIOD, 41 HOURS
T.C. NO. 3
T.C. NO. 2
T.C. NO. 1
TEMPERATURE (DEGREES F.)
0 200 400 600 800 1000 1200 1400 1600
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 49 72-1/2
ELAPSED TIME (HOURS)

Figure 9.--Temperatures in kiln charge number 2, metal beehive $\frac{1}{2}$-cord kiln.

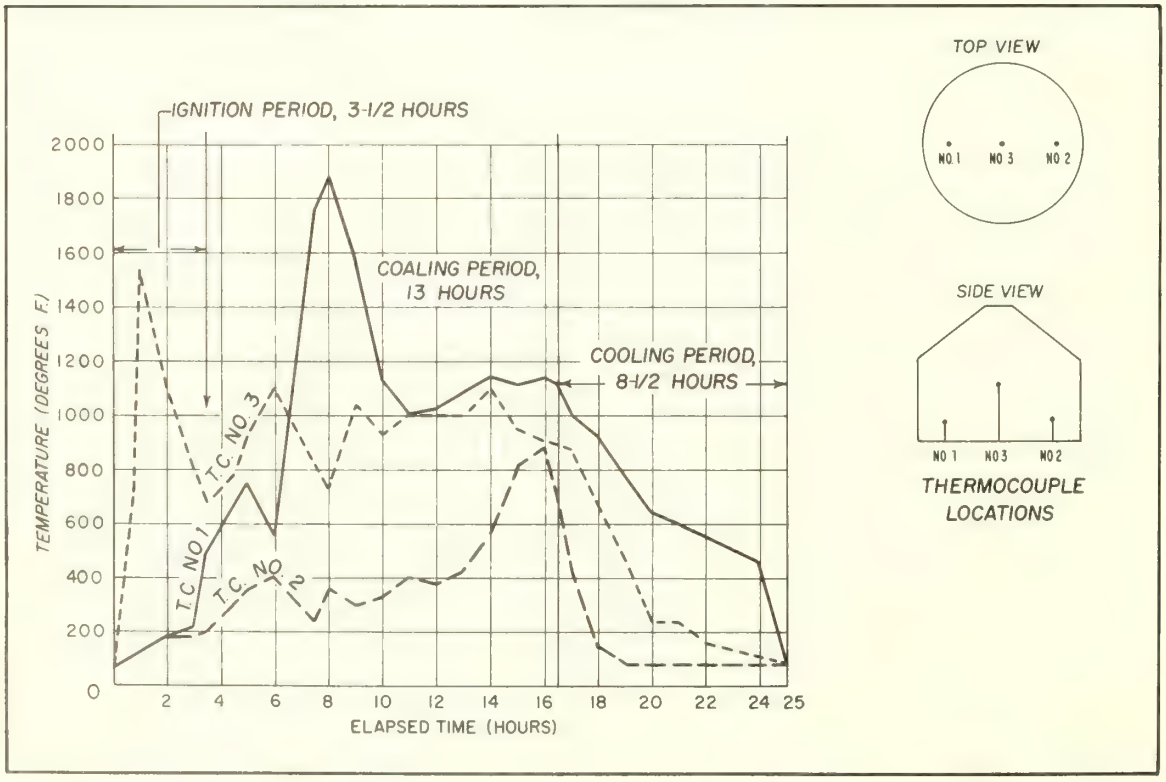
TOP VIEW
NO 1 NO 3 NO 2
SIDE VIEW
NO 1 NO 3 NO 2
THERMOCOUPLE LOCATIONS
IGNITION PERIOD, 3-1/2 HOURS
COALING PERIOD, 13 HOURS
COOLING PERIOD, 8-1/2 HOURS
T.C. NO. 1
T.C. NO. 3
T.C. NO. 2
TEMPERATURE (DEGREES F.)
0 200 400 600 800 1000 1200 1400 1600 1800 2000
2 4 6 8 10 12 14 16 18 20 22 24 25
ELAPSED TIME (HOURS)

Figure 10.--Temperatures in kiln charge number 1, metal beehive $1\frac{1}{2}$-cord kiln.

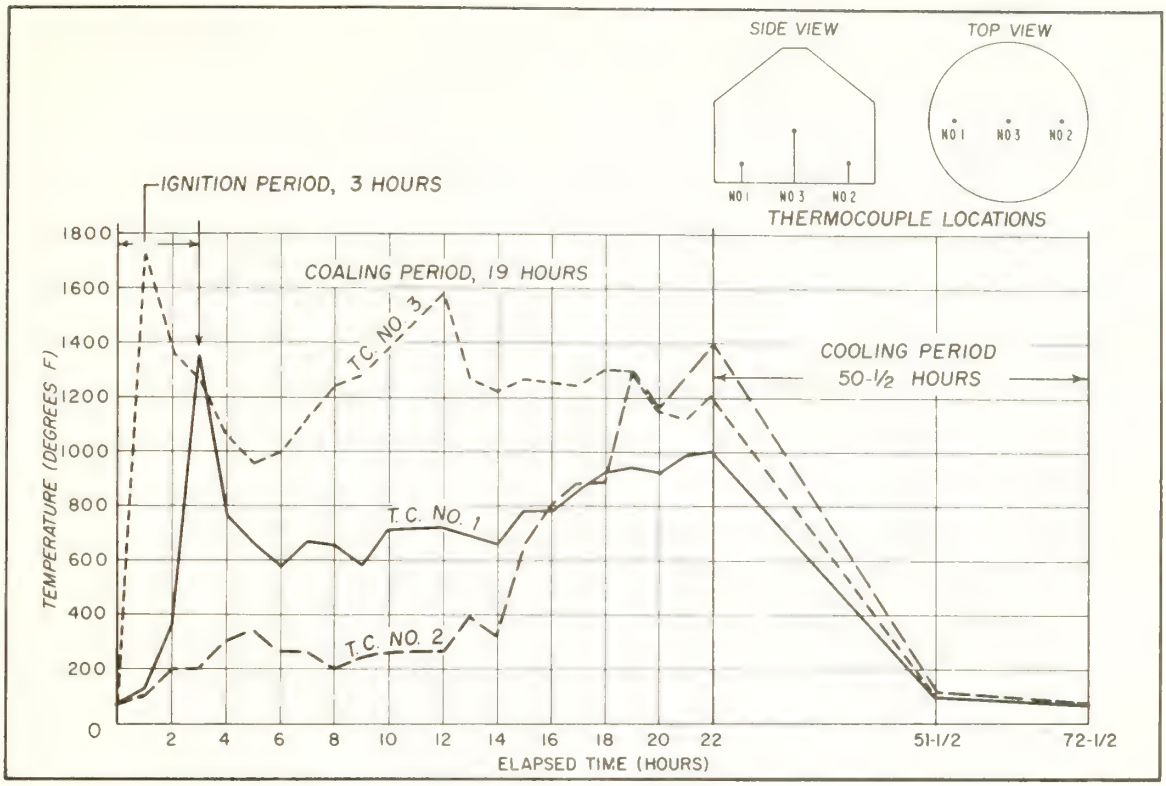

Figure 11.--Temperatures in kiln charge number 2, metal beehive $1\frac{1}{2}$-cord kiln.

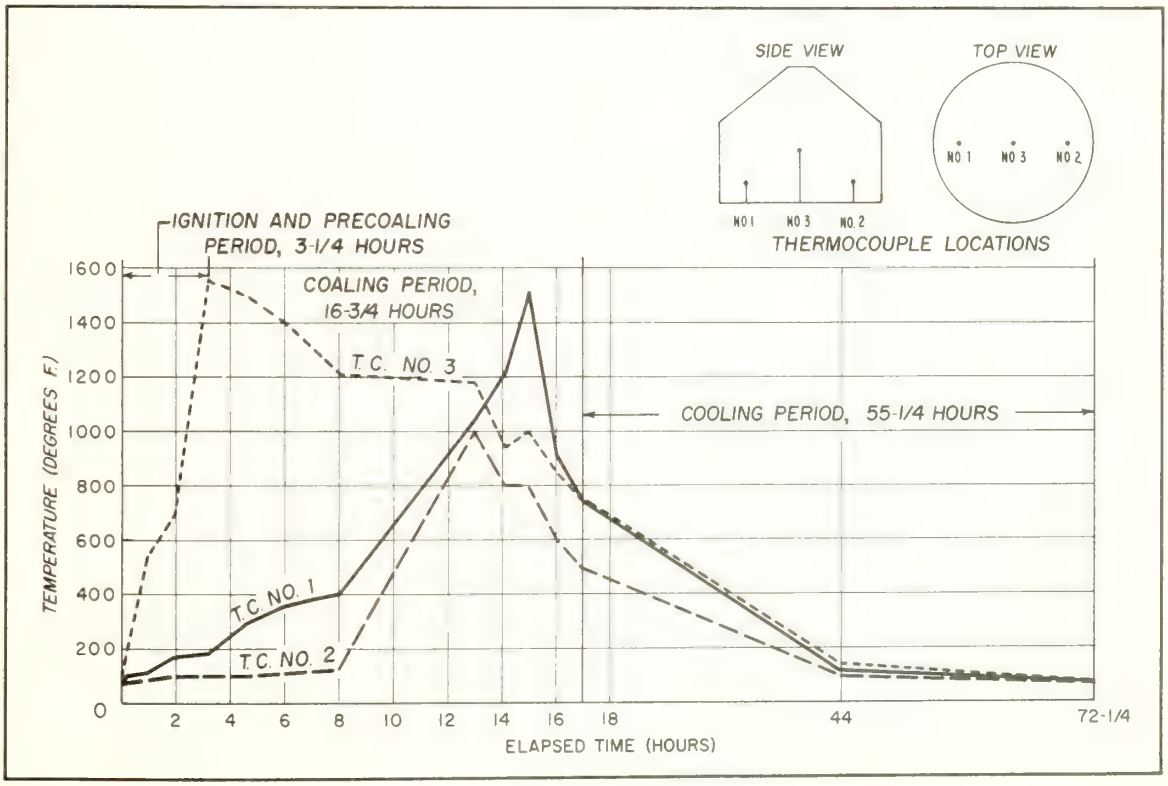

Figure 12.--Temperatures in kiln charge number 3, metal beehive $1\frac{1}{2}$-cord kiln.

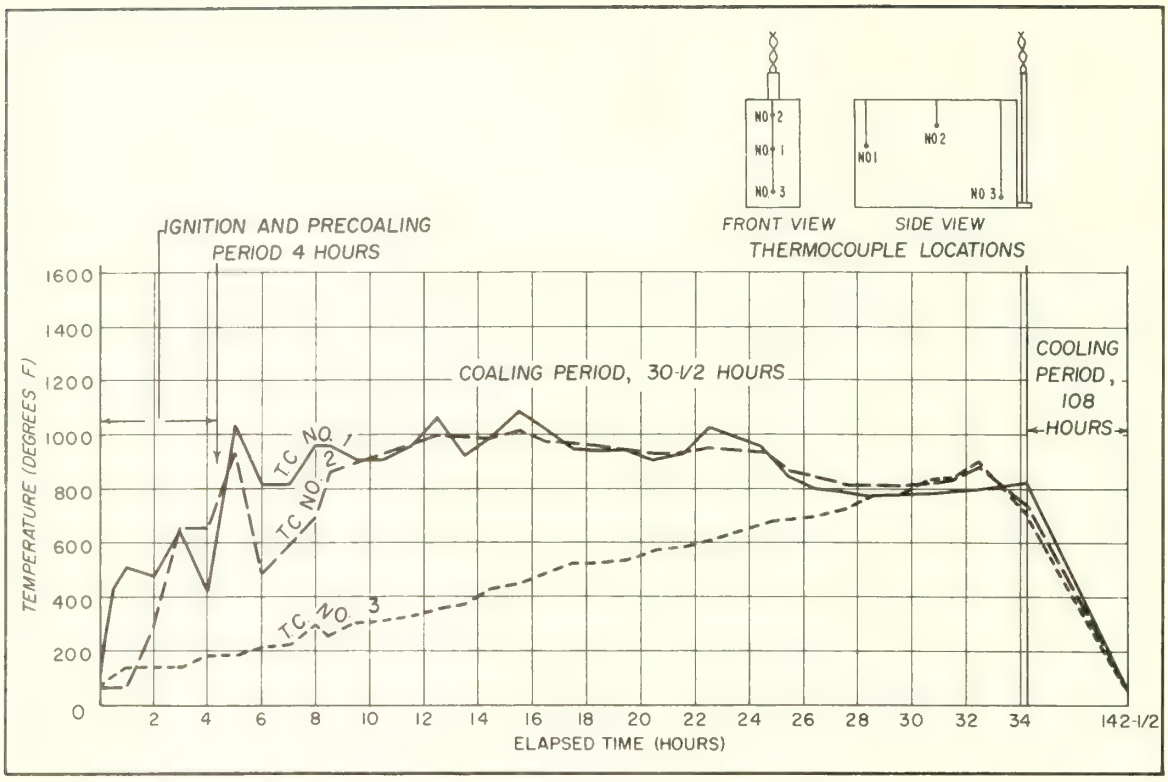

Figure 13.--Temperatures in kiln charge number 1, cinder block kiln.

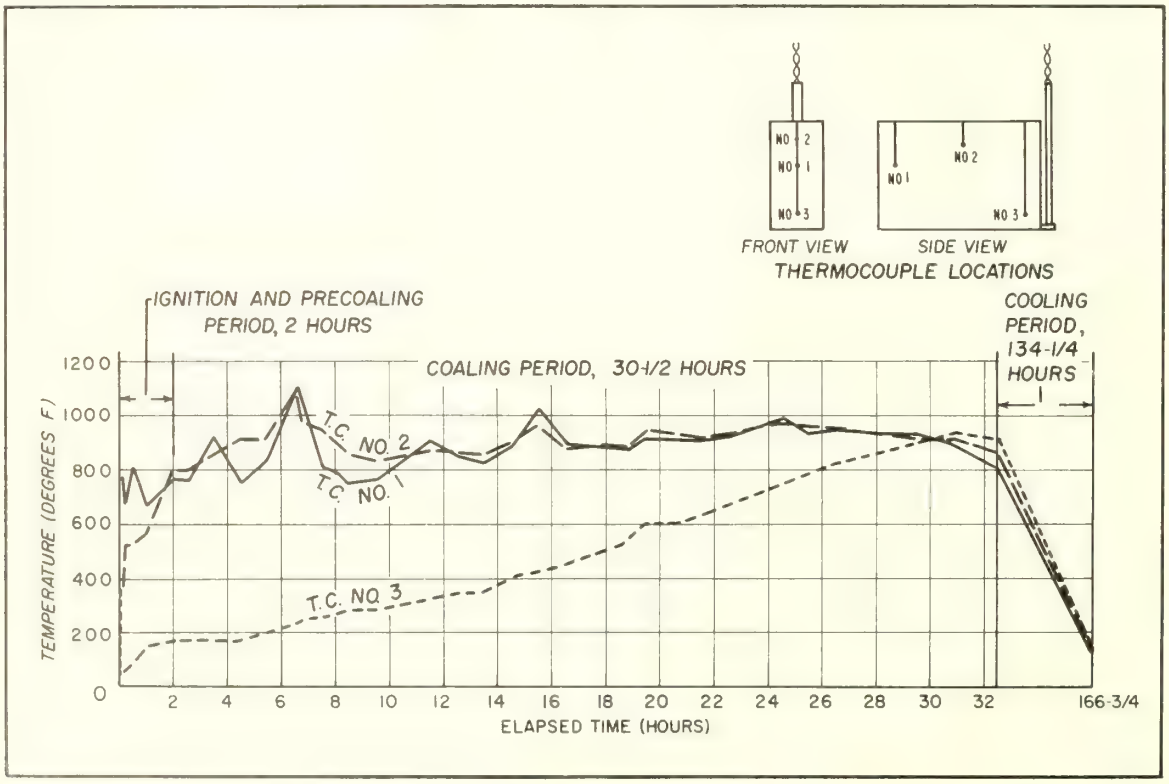

Figure 14.--Temperatures in kiln charge number 2, cinder block kiln.

Analysis of Costs

The direct labor costs for producing a ton of charcoal in the three types of kilns vary only slightly. These costs are based on estimated labor requirements at $1.00 per hour. Also, they are based on the theory that for efficiency and conservation of labor, a sufficient number of kilns of each type would be operated at one time to keep 2 or 3 men employed full time. Roughly, this would mean that 2 men would require about twelve $\frac{1}{2}$-cord kilns or five $1\frac{1}{2}$-cord kilns or three 2-cord masonry block kilns to keep them occupied for 40 hours per week. On a basis of this limited study, the direct labor cost varies only from $23.35 to $26.12 per ton of charcoal produced (table 3).

A closer look at the estimates of direct labor cost indicates that the masonry block kiln is considerably cheaper to load and unload, but it costs more for labor during the burning and cooling periods (the reason being that close temperature control and inspection is needed to maintain optimum coaling conditions). This extra labor, however, is more than offset by higher yields and lower depreciation.

Table 3.--Summary of direct labor cost data from charcoal runs [1/]

Kiln type and capacity	Runs	Cost per ton of charcoal produced					
		Loading	Burning	Cooling	Unloading	Weighing	Total
	Number	Dollars					
Metal, $\frac{1}{2}$-cord	4	8.61	3.46	.99	9.82	3.30	26.12
Metal, $1\frac{1}{2}$-cords	3	8.82	3.35	.50	8.57	2.12	23.35
Cinder block, 2-cords	2	5.41	5.95	3.67	6.91	2.12	24.05

1/ Since the direct labor costs are based on the labor requirement at $1.00 per hour, this table also shows the number of man-hours required to produce a ton of charcoal.

Not included in table 3 is the stumpage cost of the wood, cutting, or handling costs. Such costs vary widely and are often the major cause for success or failure. At Bladen Lakes State Forest these costs amounted to $12.00 per cord for wood stacked on the yard at the charcoal kiln. On a basis of charcoal yields obtained in these test runs, the wood costs per ton of charcoal amounted to $28.68 for the $\frac{1}{2}$-cord metal kilns, $35.73 for the $1\frac{1}{2}$-cord metal kilns, and $24.73 for the 2-cord cinder block kiln.

An additional cost that must be charged against production is depreciation. The $\frac{1}{2}$-cord metal kilns reportedly range in price from $400 to $800 per cord capacity, averaging $600, the $1\frac{1}{2}$-cord metal kilns cost about $300 per cord capacity, and the 2-cord cinder block kiln about $250 per cord capacity. The life of these kilns is unknown but it has been roughly estimated that they will last about 200 burns. For the metal kilns this represents about 2 years; for the block kiln, which requires more time for each coaling and cooling, it represents about 4 years. On this basis, depreciation costs on these kilns at 5 percent interest per ton of charcoal would be $6.25 for the $\frac{1}{2}$-cord metal kilns, $4.42 for the $1\frac{1}{2}$-cord metal kilns, and $3.44 for the 2-cord masonry block kiln.

Summarizing these, produces the following "break-even" cost tabulation:

Kiln type and capacity	Labor	Wood	Depreciation	Total
		(Dollars per ton of charcoal)		
Metal, $\frac{1}{2}$-cord	$26.12	$28.68	$6.25	$61.05
Metal, $1\frac{1}{2}$-cord	23.35	35.73	4.42	63.50
Cinder block, 2-cord	24.05	24.73	3.44	52.22

It will be noted that the items of overhead, maintenance, and profit and risk have been omitted from the above costs. Since these variables are so closely allied with local conditions, operating methods, marketing procedures, and desired returns, it appears preferable for the purpose of direct cost comparisons to eliminate them in this study. When a complete charcoal operation is planned, they should be determined locally and included.

CONCLUSIONS

In the test runs on three types of small charcoal kilns, the total break-even costs ranged from $52 to $63 per ton of charcoal produced. Since this is about the average wholesale price of bulk charcoal in this area, a business based on the operation of any of these kilns would be on a marginal basis, unless some items of cost could be reduced.

There is little opportunity for reducing the cost of the structures used in the Bladen Lakes studies or reducing the labor cost of operating a single kiln at the minimum wage of $1.00 per hour. However, more efficient use of labor might be achieved by mechanizing the handling of materials or by operating a battery of kilns. Also, a major cost reduction can be accomplished by obtaining cheaper wood. Some operators use mill waste or woods waste. Others use cull trees that need to be removed. Such an operation would be in lieu of deading cull trees to improve forest stands, and part of the cost can be charged against forest management. Larger kilns will also accomplish a saving, as indicated by recent experimental work at Athens, Georgia, where labor and depreciation costs of a 7-cord cinder block kiln were less than those for the $\frac{1}{2}$-, $1\frac{1}{2}$-, or 2-cord kilns at Bladen Lakes.

Agriculture--Asheville

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A Bibliography on the Southern Pine Beetle

Dendroctonus frontalis Zimm.

Compiled by

E. A. Osgood

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

Joseph F. Pechanec,
Director

U. S. DEPARTMENT OF AGRICULTURE · FOREST SERVICE

A BIBLIOGRAPHY ON THE SOUTHERN PINE BEETLE
Dendroctonus frontalis Zimm.

Compiled by

E. A. Osgood, Jr.
Division of Forest Insect Research

INTRODUCTION

The southern pine beetle, Dendroctonus frontalis, Zimm., is a native insect occurring from southern Pennsylvania southward to northern Florida and westward to eastern Texas and Oklahoma. It is one of the most damaging insects of southern pine, causing losses mounting to untold millions of dollars since the first authentic records of its destructiveness by Hopkins in 1890.

This bibliography gathers together a list of the many scattered references pertaining to this species, thereby pointing out what has been done and what remains to be accomplished through future research. It covers the literature from 1890 through 1956.

The bibliography contains two major divisions--an alphabetical author list of all citations, and a subject index of selected references. The first division needs no explanation. The second division contains a list of references selected by the author as having special merit. The numbers listed in this division refer to numbered items in the alphabetical list. A single reference may be cited under several subjects.

Despite the fact that every effort has been made to include all important references for southern pine beetle, some omissions may have been made; therefore, comments and suggestions will be appreciated.

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Silvical Characteristics of Slash Pine

(Pinus elliottii, Engelm. var. elliottii)

by

Robert W. Cooper

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

Joseph J. Pechanec,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

SILVICAL CHARACTERISTICS OF SLASH PINE
(Pinus elliottii, Engelm. var. elliottii)

by

Robert W. Cooper
Lake City Research Center

Slash pine (Pinus elliottii, Engelm. var. elliottii) (15) is one of the most important pines in the Southeastern United States and one of the two southern pines worked for naval stores. Its range extends from the Coastal Plain of southern South Carolina to central Florida and southeastern Louisiana (fig. 1). The northernmost natural growth of slash pine is believed to be that located in Georgetown County, South Carolina, about latitude $33\frac{1}{2}^{o}$N. South Florida slash pine (Pinus elliottii Engelm. var. densa Little and Dorman) is known only in Florida and has only recently been distinguished as a new botanical variety; its range extends from the lower Florida Keys north to Lake Okeechobee and then in two prongs along both coasts as far north as central Florida. South Florida slash pine (16) can be distinguished from the typical slash pine by its grasslike, almost stemless seedling stage, which resembles longleaf pine, and its heavy wood with wide bands of summerwood. This silvical writeup, however, deals only with typical slash pine.

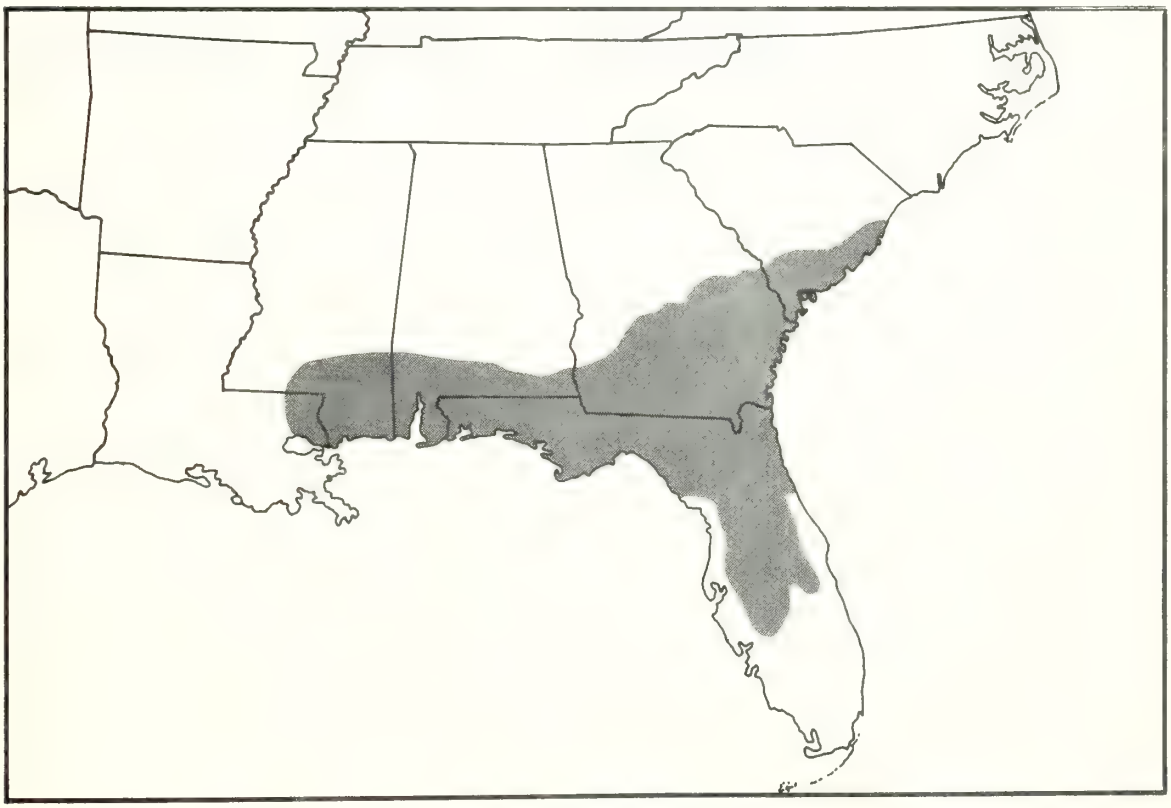

Figure 1.--Botanical range of slash pine (Pinus elliottii Engelm. var. elliottii).

Slash pine is a fast-growing tree, often reaching a height of 80 to 100 feet and a trunk diameter of 30 inches in 60 years (12). The leaves are needle-like, 8 to 12 inches long, and in fascicles of 2 and 3 on the same tree. The stalked mature cones, mostly 2 to 6 inches long, distinguish this species from the sessile-coned loblolly pine with which it may often be confused. Slash pine may occasionally be mistaken for longleaf pine, but the club-like twigs of longleaf pine help to distinguish it from the slender-twigged slash pine. The cinnamon-brown candles of slash pine also help to distinguish it from the silver-white longleaf shoots.

HABITAT CONDITIONS

CLIMATIC

Slash pine grows in the southeastern United States, a region characterized by warm, humid weather, wet summers, and drier falls and springs (25). The annual precipitation averages about 50 inches, 70 percent of which falls during a growing season of 250 days. The average annual temperature is 63°F. with occasional extremes of 106° and 0°.

EDAPHIC AND PHYSIOGRAPHIC

The soils within the natural range of slash pine are many and varied, but as a whole they are sandy, and often underlain with poorly drained hardpans. Hardpans are usually from 18 to 24 inches below the surface. Because of its susceptibility to fire injury in the juvenile stage, slash pine in the flatwoods was confined until recently to the "ponds" or pond margins where ample soil moisture or standing water provided protection. Shallow depressions which store water for part of the year and go dry for the rest are called "ponds" in the flatwoods area. Outside the flatwoods, slash pine occurred most generally in narrow bands along creeks, bays, and other minor drainages. With better fire protection, the species has now spread out between ponds, and many young slash pine stands have become established under sparse longleaf overstories. This expansion has engulfed many more soil types, including some of the sandhills, scrub-oak ridges, and less sandy soils of the Middle Coastal Plain.

Slash pine has made its best growth on pond margin sites. The typical "flatwoods" sites, which include the incompletely drained soils and the hardpan soils, are probably next in productivity. Slash pine stands are least productive on the deep, well-drained pure sands or the poorly drained lands (crawfish flats). However, some of the young plantations on the deep sands have experienced good survival and acceptable initial growth. Timber stands on old fields usually out-produce those on forest sites.

Topography does not vary much within the natural range of slash pine, but even changes in elevation of 1 or 2 feet are often accompanied by a pronounced change in soil condition and site productivity.

BIOTIC

Timber types which include slash pine as an integral member, other than pure stands of slash pine, are longleaf-slash pine, cabbage palmetto-slash pine, slash pine-hardwoods, and slash pine-tupelo. This species is also an associate of seven other forest types where these types fall within the range of slash pine (24). Some of the other important associate species of the above types are red maple (Acer rubrum var. rubrum), red gum (Liquidambar stryaciflua), sweet bay (Magnolia virginiana), loblolly bay (Gordonia lasianthus), tupelo gum (Nyssa aquatica), live oak (Quercus virginiana var. virginiana), and cabbage palmetto (Sabal palmetto). Understory vegetation commonly associated with slash pine includes saw palmetto (Serenoa repens), scrub palmetto (Sabal etonia), tall bush gallberry (Ilex coriacea), low bush gallberry (Ilex glabra), titi (Cliftonia monophylla), and waxmyrtle (Myrica spp.).

The natural range of this species is being extended by plantings, but its northern limit is restricted by the damage incurred in periodic ice storms. Plantings in the Carolina Sandhills, however, date back to 1933 and very little ice damage has been reported. It will also grow in some areas like east Texas, but does not reproduce naturally. Slash pine continues to be planted in considerably greater numbers than any other southern species.

Animal life in the slash type is represented by white tailed deer (Odocoileus virginianus), black bear (Euarctos floridanus), gray squirrel (Sciurus carolinensis), fox squirrel (Sciurus niger), cottontail rabbit (Sylvilagus palustris), and a variety of other wildlife. Among many species of birds, wild turkey (Meleagris gallopavo), dove (Zenaida macroura), and bobwhite quail (Colinus virginianus) make up the greatest part of the game-bird population. Diamondback rattlesnakes (Crotalus adamanteus), coral snakes (Micrurus fulvis), and cottonmouth moccasins (Agkistrodon piscivorus) are the more common poisonous reptiles found in this timber type. But, the most distinctive and widespread associates of slash pine in most areas are scrub cows and razorback woods hogs which have for generations been allowed to run semiwild in the forest.

LIFE HISTORY

SEEDING HABITS

Flowering and Fruiting

The flower buds of slash pine are formed in midsummer, but cannot be recognized until the following winter (23). Staminate strobili are visible about a week before the pistillate strobili. Pollen usually ripens during a 2- or 3-week period between the latter part of January and early March but the time of pollen shedding varies considerably from year to year with weather conditions. The conelets are about $\frac{1}{2}$ inch long at the time of pollen dissemination and lengthen very slowly during the first growing season, seldom more than

½ inch. Cones mature in August or September of the second year, when they should average about 5 inches in length. Seeds ripen in September, and the bulk of seed dispersal occurs in October.

Specific gravity is probably the best criterion for judging seed ripeness of slash pine cones (27, 28). When the specific gravity of freshly picked cones is 0.90 or lower, the seeds are usually ripe, and when the specific gravity drops to about 0.70 the cones begin to open on the tree. If freshly picked slash pine cones float in SAE 20 motor oil, they may be considered mature.

Seed Production

As a rule, slash pine trees seldom bear cones until they are at least 10 years old or more than 4 inches in diameter. However, they do not bear cones in large numbers until they are over 20 years old. Yields of more than 200 cones per tree are not unusual on large trees in a good seed year. Such a crop would amount to more than a pound of seed per tree, or about 15,000 seed (27). Heavy cone crops occur about once every 3 years.

Cone production may be stimulated by crown release, stem injury, or fertilization. In one study of the effect of release, a shelterwood stand of 25 to 35 stems per acre produced more cones 3 years after cutting than the fully stocked, uncut portion of the stand. Partial girdling of 20-year-old slash pine trees increased flower production nearly 100 percent.[1/] In another study normal turpentining practices (bark chipping and acid treatment) resulted in an increase of nearly 50 percent in the production of cones 3 years after the naval stores operation began. Cone production has been almost doubled by the application of 20 to 40 pounds of complete fertilizer to each tree.

Not all of the pollinated flowers survive and grow to maturity; ordinarily, less than half of them produce mature cones that contribute to the seed crop. Insects, rodents, disease, and weather make up the major factors that account for this production loss. Beetles and cone moths (Dioryctria sp.) destroy seeds and other cone tissues by their larval feeding, but their habits and the extent of damage throughout the range of slash pine are yet to be determined.

The gray squirrel and the fox squirrel often cut down many of the cones just before they mature, but longleaf cones ordinarily suffer more rodent damage than slash pine. A common disease in some sections of the belt is the pine cone rust (Cronartium strobilinum), which can reduce production considerably (14).

Weather conditions exert their greatest influence at the time female flowers are receptive; after pollination is complete, these conditions play a very small part in the production of seed within the natural range of slash pine.

1/ Hoekstra, P. E., and François Mergen. Experimental Induction of female flowers in young slash pine. Publication pending in Journal of Forestry.

Seed Dissemination

The earliest recorded slash pine seedfall in a 5-year study in north Florida was during the first week of September. More than 75 percent of the total seed for these 5 years fell during the month of October, but a few seed fell as late as March. The quality of seed usually varies proportionately with quantity produced.

Slash pine seed are winged and generally disseminated by wind. Although some seed has been carried as far as 250 feet, more than 90 percent of the seed falls within 150 feet of its source. Where there is a prevailing wind direction of considerable force, seedfall may be sufficiently concentrated in one cardinal direction to influence cutting practices, but such occurrences are not common.

VEGETATIVE REPRODUCTION

Natural vegetative reproduction does not usually occur on slash pine, although young slash pine will on occasion sprout from the stump. Grafting and air-layering techniques, however, have been successfully developed.

The best method, "bottle grafting," utilizing dormant scions, brings about 75 percent success on potted as well as field-grown stock. During the growing season, the cleft-graft method with succulent material for both scion and rootstock has shown promise (19). Such cleft grafts form very strong, smooth unions.

Air-layering (rooting branches while they are still part of the tree) is also successfully used on slash pine (18). Air-layering young trees with 1.2-percent indolebutyric acid in July resulted in root development on 80 percent of the treated twigs. Air-layers have a balanced root system and develop rapidly.

SEEDLING DEVELOPMENT

Establishment

In a good seed year, slash pine often establishes reproduction of many thousand stems per acre. Seed viability is usually good (50 percent or higher) and germination occurs in about 15 days with adequate moisture, light, and heat.

Normal germination and establishment can be expected during a rather extended period from November to April following seed dispersal, and varies considerably with local weather conditions. New seedlings have been observed, however, after June rains following a dry spring. Germination and early survival are best on mineral soil, but slash pine seedlings can become established on almost any seedbed with fair success if other conditions are favorable.

Rodents, birds, insects, and diseases stand out among the many factors which limit the establishment of slash pine seedlings. Seed-eating mice (Peromyscus sp.), field rats, and birds have been a continual obstacle in any direct seeding program even though rodent poisons and repellents have been successful in certain instances. It is logical to assume, therefore, that these seed-eaters play an equally important part in the establishment of seedlings from natural seedfall.

Young slash pine seedlings, particularly planted stock, are sometimes attacked and killed by Pales weevil (Hylobius pales), an insect of increasing economic importance in the Southeast (14). On cutover pine lands, where these insects may be numerous, planting should be delayed at least a year after cutting or the planting stock should be dipped in a protective insecticide. Small seedlings may be defoliated and killed by the pine webworm (Tetralopha robustella), but in most instances the infestations are not fatal. Localized nematode infestations have been reported in some nursery stock; fumigation of seedbeds with ethylene dibromide prior to sowing is a recommended preventive.

Damping-off is a common disease of young slash pine seedlings, particularly nursery stock. Effective control can be achieved by applying $\frac{1}{2}$ fluid ounce of formaldehyde in 1 pint of water per square foot of bed 5 days prior to seed sowing (14). Damping-off is not serious where the nurseries are located in deep, well-drained acid soil. Late root rot is a major nursery disease of slash pine. It is thought to be caused by either a fungus or nematode activity, or both; the rot can usually be controlled by ethylene dibromide soil fumigation (13). Southern fusiform rust has been another serious nursery disease. Control requires weekly spraying with Bordeaux mixture or Fermate from March to June. Culling visibly infected seedlings at lifting time is also recommended.

Excessively high surface temperatures occasionally cause some loss in nursery stock, but frequent watering during hot, dry periods will usually keep losses to a minimum.

Natural seedling establishment is influenced more by seed production and dissemination than by all of the previously mentioned factors combined. If weather conditions are favorable, a good seed year will generally result in the production of an adequate seedling crop.

Early Growth

Under normal conditions, slash pine seedlings start rapid height growth soon after germination. There is no "grass-stage" like that in longleaf pine. Early growth may be retarded on poor sites and "sour land," but it is not unusual for a seedling on an average site to grow one foot in height during the first growing season.

Ground competition, consisting of saw-palmetto, gallberry, grass, and other plants, probably exerts considerable influence on the early growth and development of slash pine. Seedlings that are planted or come in naturally on

old fields grow rapidly in height and stem diameter in the absence of competing vegetation. Early growth is best on moist but well-drained sites. Sites underlain with hardpan result in reduced growth during periods of extreme moisture conditions, both wet and dry.

Seasonal height growth usually starts early in March and makes most of its advance in March, April, and May (5, 21). Several spurts may occur in one season, the first spurt being the greatest. Radial growth starts about the same time, but continues for a longer period. Although radial growth is generally completed before November, studies in north Florida have shown that some radial growth occurs between November and March.

On the very best sites, and with a minimum of competing vegetation, 5-year-old slash pines may reach a height of 20 feet. Under more normal conditions, however, the 5-year-old seedlings will average 10 feet in height. Stocking or spacing does not exert a significant effect on the height growth of even-aged slash pine seedlings (1). Height growth of slash pine plantations in Florida can be estimated from two easily measured properties of the soil profile (2): depth to a fine-textured horizon, and depth to a mottled horizon. An estimate of the site index of natural stands of slash pine can be made from the following subsoil texture classifications (7): sands and loamy sands, 75; sandy loam and sandy clay loam, 80; loam, clay loam, sandy clay, and light clay, 85; silt loam, silty clay loam, silty clay, and heavy clay, 90.

Early root growth is also extensive and may be responsible for considerable suppression of younger seedlings. Evidence from interplantings in south Georgia (3) indicates that a difference of only 1 year in the age of planted slash pine can result in suppression of the younger trees. After 8 years, the interplants were only 70 percent as tall and 54 percent as large in stem diameter as the original seedlings.

Slash pine seedlings are susceptible to fire injury and easily killed when they are small. A 6-foot tree can survive a cool backfire under the best of conditions, but will suffer some loss in diameter and height growth if any crown scorch is incurred. Studies have shown that prescribed burning should not be attempted in slash pine stands until the trees are at least 12 to 15 feet tall (11).

Seedlings and young trees often suffer from attacks of fusiform rust (Cronartium fusiforme) or pitch canker (Fusarium lateritium f. pini). The spread of the rust from the branches into the stems can be reduced by maintaining heavy stand densities, which encourage natural pruning. On sites with high fusiform rust hazard (e.g., where trees of rust-susceptible oak species are abundant), longleaf pine should be favored over slash pine. The black or red oaks are more susceptible than the white oaks. Pitch canker, the other common stem disease of slash pine, occurs commonly on trunks and branches of small trees and results in an abundant flow of gum and heavy pitch soaking of the wood.

Fomes annosus, a widely distributed root-killing fungus in both Europe and North America, has caused extensive damage to planted conifers in Europe. Recently, it has been reported as causing mortality in several slash pine stands in southeastern United States (6).

Bark beetles are capable of killing large volumes of slash pine. Three species of the pine engraver beetle, Ips avulsus, Ips calligraphus, and Ips grandicollis, cause considerable loss each year, but are usually most damaging during extended dry spells. Outbreaks are frequently associated with wildfires, wind, and ice storms, lightning-struck trees, and small logging operations.

The black turpentine beetle (Dendroctonus terebrans) has become an increasingly important killer of slash pine. Although this bark beetle has taken its heaviest toll in mature trees worked for naval stores around drought-affected pond margins and flatwoods, it is capable of breeding in stumps on cutover areas and eventually attacking residual round trees.

SAPLING STAGE TO MATURITY

Growth and Yield

Mean annual growth in cords on the best slash pine sites culminates at about 20 years of age, and falls off gradually thereafter. On one of the better sites on the Olustee Experimental Forest, near Lake City, Florida, a managed stand of slash pine has produced 60 cords of pulpwood per acre in 27 years, a mean annual production of 2.2 cords per acre (8).

Diameter growth is affected by site, age, and growing space; height growth is affected by site and age.

A study in south Georgia (4) showed that diameter growth was also affected by artificial pruning if the crown ratio was reduced to less than 50 percent. Pruning up to 80 percent of the live crown, however, had little or no effect on height growth of planted slash pine. Ordinarily, slash pine tends to prune itself naturally, particularly in dense stands. In plantations and medium-stocked forests, however, early artificial pruning may be economically sound because of increased yield from clear material.

On account of the great range in site throughout the slash pine belt (site index of 50 to 110 feet in height at 50 years), it is difficult to present average growth or volume estimates without including site classes (26). A large percent of all slash pine stands, however, fall in the 70- and 80-foot site index class. In a managed forest, yields differ materially from those given for normal stands; therefore, normal yield tables will not give reliable estimates for managed stands unless adjustments are made. The average diameter and volume per acre for several stands of varying age and density under management, site index 80, are as follows (17):

Age (Years)	Trees (Number)	Average d.b.h, 100 largest trees (Inches)	Cords (Number)
	210	3.8	--
8	385	3.6	--
	720	3.4	--
	170	9.4	13
18	325	8.6	18
	630	7.9	25
	170	10.2	17
23	240	9.4	24
	500	8.9	34

A graphic presentation of plantation growth in Florida (fig. 2) indicates that the culmination of mean annual growth occurs sooner on a good site than on a poor site. Stocking has very little influence on increment rates on poor sites, as indicated by the single line representing from 200 to 1000 trees for site index 60, but it becomes increasingly important on the better sites.

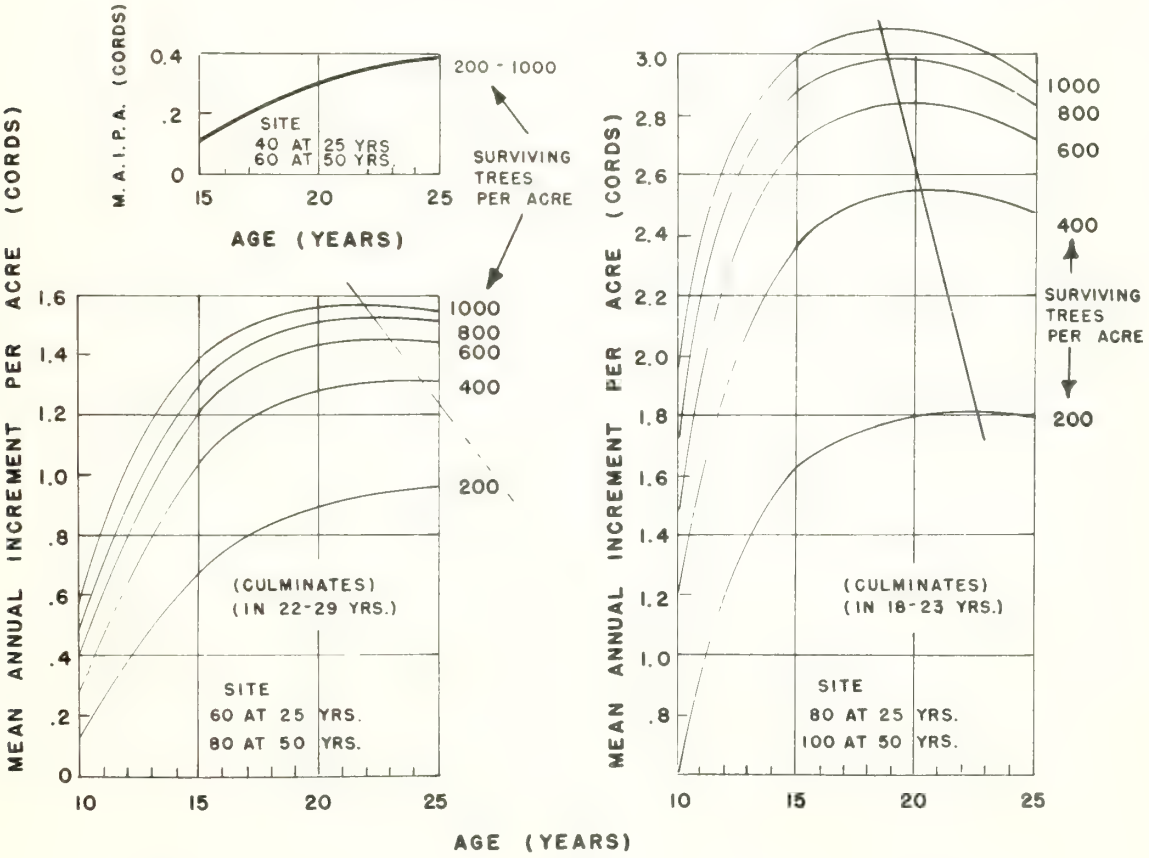

Figure 2.--Growth culmination of slash pine plantations in Florida, by W. G. Wahlenberg, after Barnes (1).

Average annual board-foot growth for site index 80 reaches its maximum at 50 years of age. Additional research is in progress to determine the growing stock needs for optimum production. For the present, however, a volume of 7 thousand board-feet (Scribner) per acre seems adequate for a 50-year rotation on an 80-foot site. Several fairly heavy thinnings will be necessary in a managed forest to maintain this volume.

Yields may be materially reduced by red heart (Fomes pini) or red-brown butt rot (Polyporus schweinitzii). Red heart is the most important decay-causing fungus in slash pine, particularly in mature and overmature trees.

Yields of gum from slash pine trees worked by bark chipping and acid treatment vary with a great number of factors. Studies have shown that large, fast-growing trees with big crowns have high gum yields (22), but some trees were found to run more gum than other trees of the same size and general appearance (20). The size of the radial resin ducts exposed by chipping, the number of resin ducts per square inch of fresh streak, and the viscosity of the gum have all been identified as factors which control gum flow.

Since tree diameter is probably the easiest characteristic to recognize in the field, the following gum-yield tabulation is presented for diameters from 9 to 14 inches, site index 70, and crown length of 35 percent (22).

Diameter at breast height (Inches)	Gum yield (Barrels per crop)
9	151
10	179
11	208
12	236
13	265
14	293

The tabulation represents a good average of naval stores stand conditions within the range of slash pine. Gum yield will decrease when crown-length is less than 35 percent and increase when it is above 35 percent. The yield probably increases on better sites and decreases on poorer sites.

Gum yields will also be affected by the occurrence of dry face and pitch streak, the latter a disorder often associated with the dry face condition. Slash pines growing on pond sites are particularly susceptible, and up to 50 or 75 percent of these trees are sometimes affected in varying degrees.

Reaction to Competition

Slash pine is intermediate in tolerance and can theoretically be managed either in all-aged or even-aged stands. It is more tolerant than longleaf pine. Even though slash pine seedlings lack longleaf's remarkable natural resistance to fire, they are invading longleaf stands, especially where cutover or poorly stocked land has been given some protection from fire.

In a dense even-aged stand of slash pine, the expression of dominance may be slow, and stagnation may result. Early thinnings are to be recommended in these instances. Under extreme conditions a precommercial thinning should be prescribed. This operation should reduce the number of stems to the point where there will be no need for further thinning before a commercial cut. Although young stands respond promptly to thinning, older stands or those in poor growing condition are often slow to respond, or occasionally fail to respond at all.

Because prescribed burning is recognized as a necessary tool of management in most slash pine stands and because this species is only moderately tolerant, even-aged management is generally favored over all-aged conditions. The use of fire for protection appears to be out of the question in all-aged stands because of the damage to young reproduction. Single-tree selections may open up holes large enough for new seedlings, but the trees will probably grow very slowly and develop suppressed characteristics.

Turpentining operations are most efficient in an even-aged forest because the faces can be concentrated. This same type of forest is also preferred where the invasion of undesirable hardwoods is a problem.

Competition from ground vegetation has been found to exert a considerable influence on the survival and growth of slash pine seedlings. This is particularly true with planted seedlings. The big difference in early height growth between trees on old-field and cutover areas is at least partially due to vegetative competition. Estimates have been made that old-field sites are from 5 to 10 feet higher in site quality than forest sites (1).

SPECIAL FEATURES

Slash pine was first recognized by Stephen Elliott in 1824, and is now named after him; however, he first thought it to be a variety of loblolly pine.

Only slash and longleaf pine have commercial value for naval stores, and because of its higher yields, more fluid gum, and less scrape, slash pine is the more important. Both gum and wood may be produced in the same stand by turpentining only the trees to be removed in the next thinning or harvest cutting. After a tree has been selected for a naval stores face, spiral gutters and aprons are attached with double-headed nails and a cup is placed below the apron to catch the gum. The rough outer and white inner bark are removed with a bark hack, making a 3/4-inch streak every 14 days from about March 15 to November 1. The freshly chipped streak is then sprayed with a 50-percent solution of sulfuric acid. All of the faced trees are harvested for sawlogs or pulpwood as soon as turpentining is complete (usually after 4 years for a single face or 8 years if back-faced), since bark beetles, turpentine borers, and fire can cause severe losses if worked-out trees are left standing. With this method, the entire butt log can be utilized with practically no waste.

RACES AND HYBRIDS

The nomenclature applied to slash pine has been a source of confusion for the past 100 years. Two distinct botanical species have been recognized and distinguished (16): Caribbean pine (Pinus caribeau Morelet), with tropical distribution in the West Indies and Central America, and slash pine (Pinus elliottii Engelm.), in the southeastern United States. In 1952, a variation of slash pine in southern Florida was officially recognized and named South Florida slash pine (Pinus elliottii Engelm. var. densa Little and Dorman). The term densa refers to the dense, heavy wood with very wide summerwood rings, to the grasslike seedlings with crowded needles, to the thick tap root, and to the thick hypoderm of the needles.

Limited trials in this country and in South Africa have not yet shown any distinct racial variation in growth rate of typical slash pine (9).

No natural hybrids of slash pine are known to exist, but it has been artificially crossed with both shortleaf pine (Pinus echinata) and loblolly pine (Pinus taeda) (10).

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Silvical Characteristics of Sand Pine

by

Robert W. Cooper

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

Joseph J. Pechanec,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

SILVICAL CHARACTERISTICS OF SAND PINE
(Pinus clausa, Chapm. Vasey)

by

Robert W. Cooper
Lake City Research Center

Sand pine (Pinus clausa, Chapm. Vasey) has only recently become one of the important forest trees of the United States; in fact, the largest sand pine concentration in the world is a block of only 280,000 acres in north central Florida. The species is also abundant locally in a narrow strip along the east coast of Florida from St. Augustine southward to Ft. Lauderdale. On the Gulf Coast, the southern limit is in the vicinity of Naples in Collier County. Small tracts of sand pine are found around Tampa and more extensive areas are abundant in western Florida between Panama City and Pensacola, extending westward into Baldwin County, Alabama (fig. 1). Many of Florida's offshore islands also support sparse stands of sand pine.

HABITAT CONDITIONS

CLIMATIC

The climate in north central Florida is characterized by hot summers with abundant precipitation and mild, rather dry winters. Annual temperature extremes of 15° and 105° F. occur, but they are not common. The average annual temperature is 70°, with an average of 84° in August and 57° in December. A frost-free period of about 275 days is normal. About 60 percent of the annual rainfall of 53 inches falls in the 4 months from June through September.

EDAPHIC

Sand pine grows on light, sandy, infertile, and slightly acid soil derived from deep deposits of marine sand and clay. The large block of sand pine in the Ocala National Forest is supported by one geological formation, the Citronelle, which is composed of sand, gravel, and occasional strands of clay. Most of the sand is classified as fine textured and well drained, with three distinct soil series: St. Lucie, Lakewood, and Kershaw. The permanent wilting percentages for these soils are 0.63, 0.65, and 0.73 percent, respectively.[1/]

The sand pine of western Florida grows on shallow littoral deposits which were the bottom of the sea during previous high-water levels.

1/ Beal, J. F. A study of the wilting percentages of sandy soils of the Ocala National Forest and their effect on the regeneration of sand pine. Master's thesis, University of Florida. 71 pp. 1951.

Figure 1.-- Range of sand pine.

Site variation is not significant throughout most of the range of this species.

PHYSIOGRAPHIC

The north central part of Florida is known as the Central Highlands. This region ranges in altitude from 200 feet to less than 40 feet above sea level. The higher parts, where the depth to ground water is great, are pitted with innumerable sink holes and artesian springs. Gentle rolling hills characterize the bulk of the sand pine terrain.

The western part of Florida, known as the Western Highlands and Coastal Lowlands, support most of the sand pine in that area. An unusual feature of this region is the steepness of the heads of many streams.

BIOTIC

The sand pine of north central Florida grows in dense, even-aged, pure stands which originated as a direct result of past fires. It is known locally as "Ocala sand pine," and is characterized by serotinous cones which remain tightly closed for many years unless opened by the heat of a wildfire. It is a relatively short-lived tree (70 years maximum) that grows to a height of 70 feet and a normal maximum diameter of 18 inches. It is sometimes found in the longleaf pine-scrub oak type, but is seldom associated with any of the other common southern timber types. Type lines are very pronounced; in many instances roads run along type lines, with sand pine on one side and longleaf on the other.

By contrast, west Florida sand pine, popularly known as "Choctawhatchee sand pine," frequently occurs in uneven-aged stands and often invades oak land. This stand difference is probably caused by the fact that its cones open more readily than those of Ocala sand pine and it does not need killing fires to reproduce itself.

Vegetation commonly associated with sand pine includes rosemary (Ceratiola ericoides), saw-palmetto (Serenoa repens), scrub palmetto (Sabal etonia), Chapman oak (Quercus chapmanii), live oak (Quercus virginiana), sand live oak (Quercus virginiana var. maritima), scrub oak (Quercus myrtifolia), and turkey oak (Quercus laevis). All of these species are in the understory.

The sand pine type, in combinations with other forest types, supports a sizeable population of white-tailed deer (Odocoileus virginianus) and was a popular hunting ground long before it was considered for its wood production. Other animal associates include the black bear (Euarctos floridanus), the gray squirrel (Sciurus carolinensis), the fox squirrel (Sciurus niger), the wild hog (Sus sp.), and the cotton-tail rabbit (Sylvilagus palustris). Common birds include doves (Zenaidura macroura), chewinks (Pipilo erythrophthalmus), blue jays (Cyanocitta cristata), and an occasional wild turkey (Meleagris gallopavo). Seed-eating rodents, particularly the white-footed or deer mice

(Peromyscus floridanus and Peromyscus polionotus), are widespread and have an important bearing on the regeneration of sand pine. Diamond back rattlesnakes (Crotalus adamanteus), coral snakes (Micrurus fulvius), and ground rattlers (Sistrurus miliarius), are the most common poisonous reptiles found in this timber type.

LIFE HISTORY

SEEDING HABITS

Flower buds of sand pine are formed early in the summer and become discernible the following December. Pollen usually ripens between December 20 and January 10. Conelets grow very little the first year, but they develop quite rapidly during the spring of the second year and reach mature size by late summer. The seeds, about 75 per cone, ripen in October; viability of fresh seed averages 75 to 80 percent. A pound contains 60,000 to 70,000 seed.

Seed Production and Dissemination

Sand pine bears cones at an early age and usually produces heavy cone crops every year. Mature cones frequently occur on 5-year-old trees. The species is similar to jack pine (Pinus banksiana) and lodgepole pine (Pinus contorta), in that the cones are very persistent and serotinous. The specific name clausa, meaning closed, refers to this feature (fig. 2).

Figure 2.--The crown of a young sand pine tree loaded with closed cones.

This closed-cone characteristic occurs mostly in the Ocala sand pine growing in peninsular Florida. Unmanaged stands of these trees have in the past regenerated from wildfires. When a killing fire sweeps through such a stand of cone-bearing trees, the cones open and release tremendous quantities of seed. More than one million seed per acre were recorded after one such fire (1). But when a sand pine stand below cone-bearing size is burned, very few seeds are dispersed, and reproduction does not come back. The persistence of closed cones on Ocala sand pine causes an accumulation of cones of many ages on one tree, and the viability of seed in these cones decreases rapidly with age (3); in fact, only 10 to 20 percent of the seed in a 5-year-old cone is viable. Very little sand pine seed is released naturally from standing trees, and the greatest number of viable seed recorded annually was 16,000 per acre, most of which fell during the hottest summer months. Tightly closed cones on the tops of harvested trees, however, open and release their seed when subjected to high surface temperatures (2). The seed so released from sand pine slash is important in obtaining adequate regeneration following harvest cuttings in central Florida.

The situation in western Florida is somewhat different. Here, among the Choctawhatchee sand pine, open cones are much more frequent. Stands of sand pine in west Florida are expanding as a result of fire protection (the same holds true of longleaf islands in the Ocala).

SEEDLING DEVELOPMENT

Sand pine seed are often consumed by rodents, principally the white-footed or deer mouse (Peromyscus floridanus), Florida harvester ants (Pogonomyrmex badius), and birds. The influence of these seed eaters is quite important in cutover stands where seed release occurs over an extended period of time. After killing fires, however, complete seed release usually takes place within a month's time in quantities sufficient to satisfy the demands of both regeneration and the seed-eating population.

Another condition limiting sand pine germination and survival is the lethal surface soil temperatures which occur during 8 months of the year. Soil surface temperatures of 162° F. have been recorded during June. Normal germination usually occurs from November through January, when surface temperatures are sublethal, or less than 130° F., as suggested by Haig (4).

Given adequate moisture and favorable germinating temperatures, sand pine seeds usually germinate in 15 days. New radicles dry out easily if temperatures are high and moisture is low; many seed fail to develop into seedlings because of these conditions. Root penetration is quite rapid if the radicles escape these extremes; germinating seed develop a radicle at least 2 inches long within 10 days after emergence. On bare areas, where the soil 2 inches or more below the surface rarely loses enough moisture to reach its wilting point, established seedlings seldom die because of moisture deficiencies. With a normal amount of vegetative competition, however, the increased loss of moisture may result in the death of young, established plants. Young sand pine seedlings are also susceptible to frost damage, damping-off, root rot, and nematode injury.

Germination may occur at almost any time of the year, but many of the seedlings that begin their lives during the hot months of the year succumb. Even after the heavy seedfall of a killing spring fire, successful seedling establishment does not usually occur until November or December.

Seedlings usually experience two growth spurts each year; the first takes place in March and April and the second late in the summer, usually September. Height growth varies considerably but may be as much as 24 inches annually. A normal 3-year-old seedling with little competition will average about 3 feet in height.

Sand pine seedlings are not easily transplanted, although once established they become quite hardy. Root disturbance and the other shocks which accompany lifting and planting usually result in early mortality. Under the best of conditions, survival will not average much above 50 percent. Competition for moisture may be one of the determining factors, however, since acceptable survivals have been obtained from plantings on cleared ground. Young seedlings often suffer deer browsing, which induces excessive branching. Since young sand pine trees develop into nice Christmas trees, there is considerable interest in growing them for such a crop.

SAPLING STAGE TO MATURITY

After establishment, sand pine is quite resistant to temperature extremes, drought, insects, and disease. The trees often develop a lean from high winds, but uprooting is not common. Sand pine trees are, however, easily killed by fires, and wildfires in the sand pine type are difficult to control. Hot ground fires with accompanying needle scorch kill as readily as do true crown fires. Fires move rapidly in dense stands with relatively little ground fuel, as well as where there is an accumulation of inflammable material. In fact, most of the disastrous burns have occurred in well-stocked stands, where the fire moves from crown to crown with astonishing speed.

Because of the closed-cone characteristic of the sand pine trees of central Florida, clear-cutting during the summer, fall, and early winter is the most feasible way of obtaining natural reproduction. The cones lying close to the ground on slash from felled trees will open, releasing seed at a time when soil moisture and ground temperatures are favorable for germination and establishment. Mechanical ground scarification and partial lopping and scattering of cone-bearing branches from the tops of harvested trees usually improves stocking and distribution.

The stands of western Florida are more adapted to conventional methods of cutting.

Sand pine is not highly susceptible to diseases. Round galls (Cronartium cerebrum) are common, but seldom serious. Mature trees are subject to redheart (Fomes pini), especially where large branch stubs are common.

The black turpentine beetle (Dendroctonus terebrans), southern pine beetle (Dendroctonus frontalis), and Ips engraver beetles (Ips sp.) may cause mortality of sand pine, particularly in trees injured or weakened by fire or lightning. Insect borers such as the southern pine sawyer (Monochamus titillator) also may quickly invade weakened trees. The red-headed pine sawfly (Neodiprion lecontei) occasionally defoliates sand pine, and pitch moth larvae (Dioryctria sp.) frequently damage twigs and cones.

Growth and Yield

Sand pine is often described as "scrub pine" because of its poor form, but under certain conditions it grows well and develops into a good pulpwood tree. Although an occasional tree on better sites will grow to a diameter of 26 inches and a height of 75 feet, smaller sizes are more common (fig. 3). As a result, most of the trees are cut for pulpwood and used to make sulphate pulp. Sand pine lumber is susceptible to early decay when exposed to the elements, but it may be used for interior work where strength is not of primary importance.

Figure 3.--Dense stand of 35- to 40-year-old sand pine on an average site on the Ocala National Forest.

On the best sites, site index 70, the trees should average 16 to 18 inches in diameter and 70 feet in height at maturity. On average sites, site index 60, the trees should average 12 to 13 inches in diameter and 60 feet in height at maturity. On the poor sites, site index 50, the trees should average 8 to 10 inches in diameter and 50 feet in height at maturity.

Estimates of yield are guesses, since very few sand pine stands have been managed for optimum yields. Yields of 20, 15, and 10 cords per acre are predicted for high, average, and poor sites, respectively, at 40 to 45 years (rotation age) in well-stocked stands. Stands tend to break up considerably after they reach 50-60 years of age. Yields for sand pine plantations on the same sites are expected to exceed these figures, but none of the plantations has reached merchantable size to date.

Reaction to Competition

Sand pine has been rated as moderately intolerant, but in its early establishment it is rather tolerant to shade and competition, becoming more intolerant with age. It expresses very little dominance in its usual growth pattern.

SPECIAL FEATURES

The closed-cone characteristic and its regeneration capacity following a killing wildfire are sand pine's only claim to fame. Its adaptability to severe sites, however, brands it as a possibility for other dry, unproductive sites in the South. If and when its transplanting difficulties are overcome, this possibility may become a reality.

RACES

The sand pines of western Florida, particularly those between Panama City and Pensacola, are characterized by open cones. Instead of the dense, even-aged, closed-cone stands of eastern Florida, the stands are more uneven-aged, the trees are less crowded, and good reproduction can be found in the openings. No morphological differences have been found between the sand pine trees from those two geographic areas in Florida, but common names to distinguish the races are in use (5). The typical sand pine with closed cones is called Ocala sand pine or Ocala race; the sand pine of western Florida with open cones is called Choctawhatchee sand pine or Choctawhatchee race.

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en Years of
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n the Southern Appalachians

Robert A. Campbell

SOUTHEASTERN FOREST
EXPERIMENT STATION
Asheville, North Carolina

Joseph F. Pechanec,
Director

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

TEN YEARS OF EXPERIMENTAL FARM WOODLAND MANAGEMENT IN THE SOUTHERN APPALACHIANS

by

Robert A. Campbell
Southern Appalachian Research Center

Farm woodlands account for about 40 percent of the total woodland area of the Southern Appalachians. With proper care they could supply an important part of the forest product needs of the region and at the same time provide a sizeable supplement to the cash farm income. Few such properties are now operating at top capacity in either respect.

To determine the actual returns possible from planned farm woodland management, and to provide demonstration woodlands, four separate areas on the Bent Creek Experimental Forest, near Asheville, North Carolina, were set aside in 1945. These areas are representative of many farm holdings in acreage as well as in character of the timber stand. The cutting plan for each tract called for the removal of some products annually, and the use of such labor and equipment as a farmer would have available. Cutting during the past 10 years has gradually removed defective and poorly formed trees in addition to species of low value. Future cutting will be scheduled to allow the desired amount of growing stock to build up, after which it will be sustained at about the same level as annual growth.

Two of the tracts, Woodlands 1 and 2, are being managed for small products such as small saw logs, pulpwood, and fuelwood; the other two, Woodlands 3 and 4, for large, high-quality products such as large saw logs and veneer logs. Pulpwood and fuelwood are removed in thinnings from appropriate areas and from topwood left in the sawtimber operation. Other products such as locust posts and dogwood bolts are cut and sold when markets and supply of products permit.

Stand Description and Treatment

These stands are typical of the region, in that they were repeatedly culled and burned prior to the late 1920's. Since then they have been protected from fire and trespass but have had no other management until recently. Starting in 1946 and continuing every year since, some cutting has taken place in each woodland through 1955 (fig. 1). All cutting during the first 8 years was solely in the nature of an improvement to remove defective, overmature trees and thin overdense stands. During 1954 and 1955, some sound and thrifty trees in Woodlands 1 and 2 were cut to increase the difference in average tree size between large-product areas and small-product areas, so that the management comparison would be more meaningful. During the

Figure 1.--Above, cove site immediately after formative cut. Below, cove site 10 years later, showing the new crop in early stages.

first 10 years, comparisons between the large- and small-product woodlands have not had much meaning because most of the harvested sawtimber came from large trees already present on both types of tract when they were first established.

As a result of this formative cut, both saw-log and cordwood stocking have been reduced below their starting level. Most of the reduction took place in Woodlands 1 and 2, as shown in table 1 and figures 2, 3, 4, and 5.

Table 1.--Original stand in 1946, as compared to stand in 1951 and 1956, on a per-acre basis

Year	Trees	Basal area	Volume		Annual net 1/ growth		
			Diameter class		Diameter class		All size classes
			5 to 10 inches	10+ inches	5 to 10 inches	10+ inches	
	Number	Square feet	Cords	Board-feet	Cords	Board-feet	Cubic feet
WOODLAND 1							
1946	247	105	18.2	4900	--	--	--
1951	208	93	14.0	5200	-0.14	140	17
1955	141	65	10.0	3800	-0.20	205	24
WOODLAND 2							
1946	89	63	7.2	5400	--	--	--
1951	101	65	7.5	2/ 4700	0.17	260	67
1955	88	52	7.0	3300	-0.04	205	37
WOODLAND 3							
1946	148	75	10.7	5000	--	--	--
1951	146	75	11.4	4700	0.27	210	65
1955	121	63	8.0	4300	-0.21	180	18
WOODLAND 4							
1946	114	72	9.1	5900	--	--	--
1951	109	72	8.7	2/ 6100	0.04	300	63
1955	99	68	8.0	5900	0.07	180	42
COMBINED							
1946	149	79	11.3	2/ 5400	--	--	--
1951	140	76	10.4	5300	0.09	230	54
1955	110	63	8.0	4600	-0.07	190	32

1/ The growth figures include the volumes cut during each 5-year period.

2/ Varies from previous reports because of exclusion of cull tree volume and/or different volume tables.

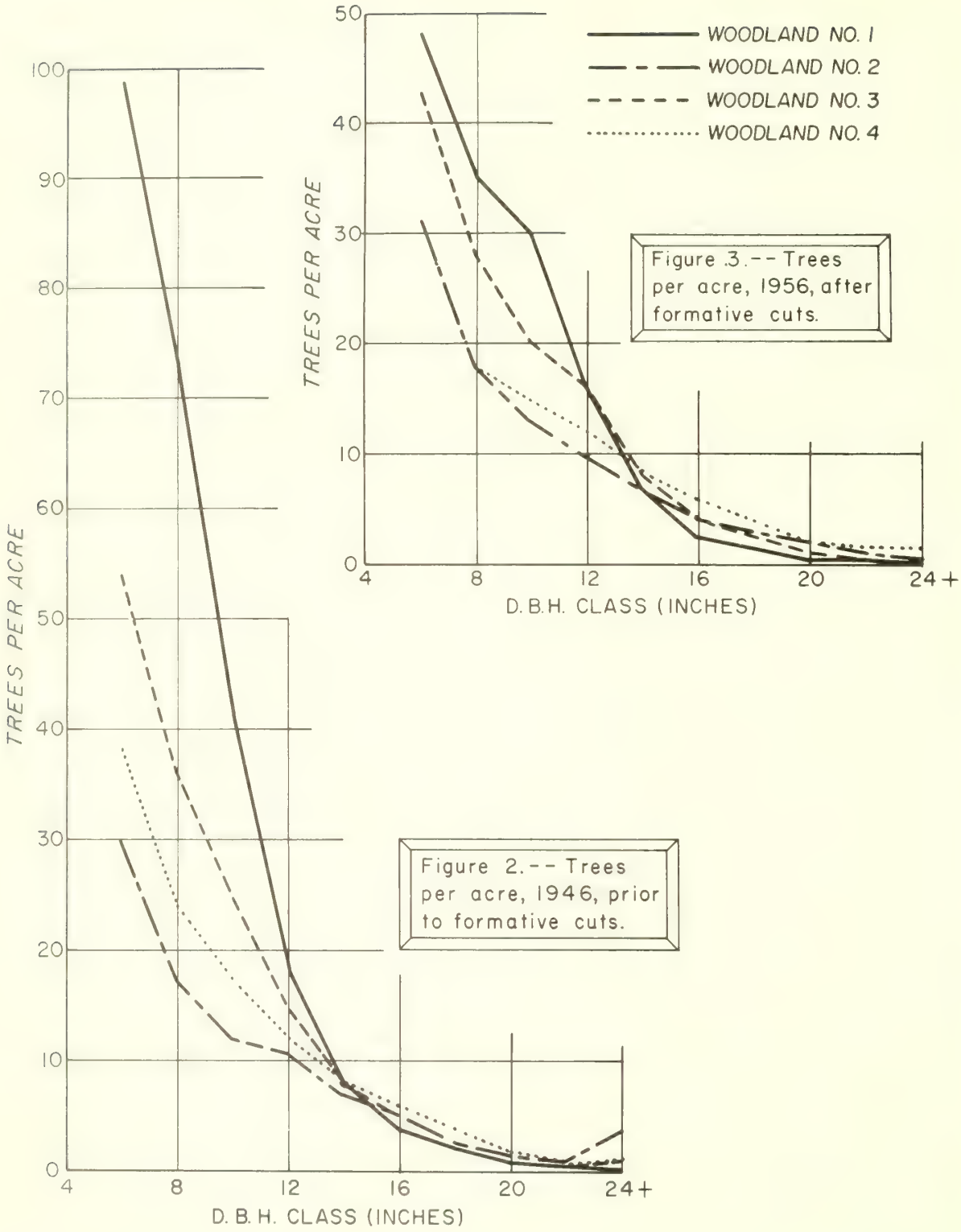
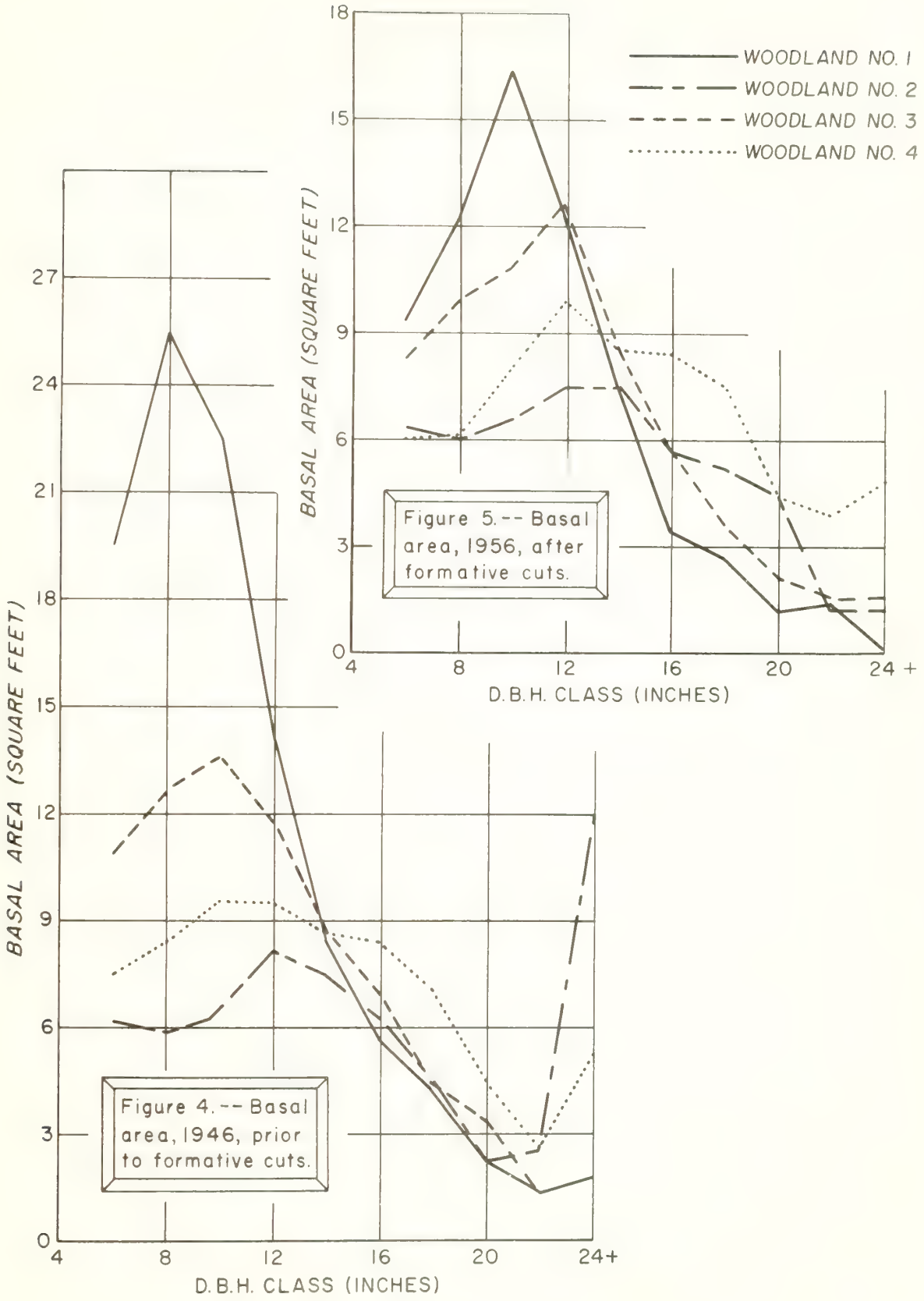


Figure 3.-- Trees per acre, 1956, after formative cuts.

Figure 2.-- Trees per acre, 1946, prior to formative cuts.


WOODLAND NO. 1
WOODLAND NO. 2
WOODLAND NO. 3
WOODLAND NO. 4
BASAL AREA (SQUARE FEET)
D.B.H. CLASS (INCHES)
0
3
6
9
12
15
18
4
8
12
16
20
24 +
Figure 5.-- Basal area, 1956, after formative cuts.
BASAL AREA (SQUARE FEET)
D.B.H. CLASS (INCHES)
0
3
6
9
12
15
18
21
24
27
4
8
12
16
20
24+
Figure 4.-- Basal area, 1946, prior to formative cuts.

The need for rebuilding growing stock on these two areas will require a "stretch-out" between harvests in order to make an economic cut. While there will still be an annual harvest from one or more of the woodlands, the bulk of the cut from each will be removed in one year.

During the second 5 years, cubic foot growth on all woodlands combined was considerably less than it was for the first 5 years. However, the growth for the second period was reasonably good considering the drought conditions that existed from 1952 through 1954. The average annual growth of pole-timber-sized trees decreased materially, from plus 0.09 cord to minus 0.07 cord per acre. Insect damage in 1953 accounts for part of this decrease; movement of pole timber trees into sawtimber sizes accounts for the rest. The board-foot growth of sawtimber trees also declined on all areas except Woodland 1. The net result was a 17-percent decline in board-foot growth from 230 to 190 board-feet per acre per year (table 1). Oddly enough, the board-foot growth on the two small-product areas is the same (205 board-feet per acre), and on the two large-product areas it is identical (180 board-feet per acre). Within the range of residual stockings carried, the growth-volume relationship did not form any regular pattern. The growth (table 1) is the growth of the stands after cutting, with no allowance made for defect in merchantable trees. The volume harvested (table 2) is based on net log scale, not upon tree estimates.

All trees were graded on a butt-log tree-grade system, starting with the first inventory in 1946 and at each successive inventory. Desirable as a quality comparison might be, it would not have much meaning at present because of changes in grading standards introduced in the early 1950's. Furthermore, changes in quality between the first and second inventories (a 5-year period) would represent largely the harvest of old-growth material and a reduction of cull trees. Much of the better old-growth timber was of high quality, but it was mature and earning only a low rate of interest.

Harvest Returns

During the second 5-year period, the total stumpage value of the harvests was greater by about one-half than during the first 5-year period (table 2). This increase was caused mainly by a general rise in stumpage prices, and a larger volume of cordwood cut during the second 5-year period because of a growing demand for pulpwood. Also contributing to the increase were a higher proportion of good logs and better appraisals. In comparison with prices bid for national forest stumpage of the same species, grade, and accessibility, the stumpage prices obtained for the sawtimber from these woodlands were low. Nevertheless, they more than doubled during the 10-year period. The volume of sawtimber harvested was only slightly larger during the second 5-year period than during the first. The cordwood volume, however, was 50 percent greater, and this increase resulted in $2\frac{1}{2}$ times more cordwood stumpage return than during the first 5-year period. Much of the increase in value was due to the fact that all hardwood cordwood was sold as fuelwood during the first 3 years, whereas pulpwood markets paying a higher rate were available thereafter.

Table 2.--Volume and value of forest products harvested per acre, 1946-1955

Period	Timber products				Other		Value of all products		
	Saw logs	Fuel and pulpwood	Posts	Total	Xmas trees	Tan-bark	On stump	At roadside	F.o.b. market
	Board-feet	Cords	Number	Cubic feet 1/	Number	Tons	Dollars		
WOODLAND 1									
1946-1950	520	1.51	--	232	--	--	5.00	19.00	32.00
1951-1955	1600	7.86	--	985	--	--	35.00	111.00	168.00
Total	2120	9.37	--	1217	--	--	40.00	130.00	200.00
Yearly average	210	.94	--	122	--	--	4.00	12.96	19.95
WOODLAND 2									
1946-1950	1620	4.92	--	743	--	0.45	18.00	75.00	113.00
1951-1955	1900	1.95	--	545	--	--	36.00	76.00	109.00
Total	3520	6.87	--	1288	--	.45	54.00	151.00	222.00
Yearly average	350	.69	--	129	--	.04	5.36	15.15	22.25
WOODLAND 3									
1946-1950	970	0.67	0.9	252	--	--	11.00	25.00	38.00
1951-1955	900	2.60	--	400	0.7	--	16.00	47.00	72.00
Total	1870	3.27	.9	652	.7	--	27.00	72.00	110.00
Yearly average	190	.33	.1	65	.1	--	2.72	7.27	11.08
WOODLAND 4									
1946-1950	1230	1.13	7.7	342	--	--	19.00	42.00	59.00
1951-1955	710	1.11	3.0	237	--	--	11.00	27.00	38.00
Total	1940	2.24	10.7	579	--	--	30.00	69.00	97.00
Yearly average	190	.22	1.1	58	--	--	3.00	6.91	9.75
ALL WOODLANDS									
1946-1950	1120	1.82	3.0	377	--	0.1	14.00	40.00	59.00
1951-1955	1150	2.87	1.1	473	0.2	--	21.00	57.00	84.00
Total	2270	4.69	4.1	850	.2	.1	35.00	97.00	143.00
Yearly average	230	.47	.4	85	--	--	3.55	9.69	14.34

1/ Based on 85 cubic feet per cord and 5 board-feet per cubic foot, 1 cubic foot per post.

It is expected that returns will decrease during the coming 5-year period, especially on Woodlands 1 and 2 while the growing stock is being rebuilt. The high returns per acre per year of $4.00 and $5.24 shown in table 2 for Woodlands 1 and 2, respectively, will drop sharply because much of the large and high-quality sawtimber was harvested in 1954 and 1955. On the other hand, cutting on Woodlands 3 and 4 will probably continue at about the 10-year average of 200 board-feet and $\frac{1}{4}$ cord per acre per year until the stand volumes are built up to the desired levels, when the cut can be increased. Stumpage returns per acre per year for each woodlot are shown in figure 6. The 10-year average for all woodlots combined was $3.55. On a basis of current prices, the average annual stumpage return for the 10-year period would be about $5.00 per acre. Figure 7 shows how the market dollar was divided among stumpage, logging, and hauling during the past 10 years.

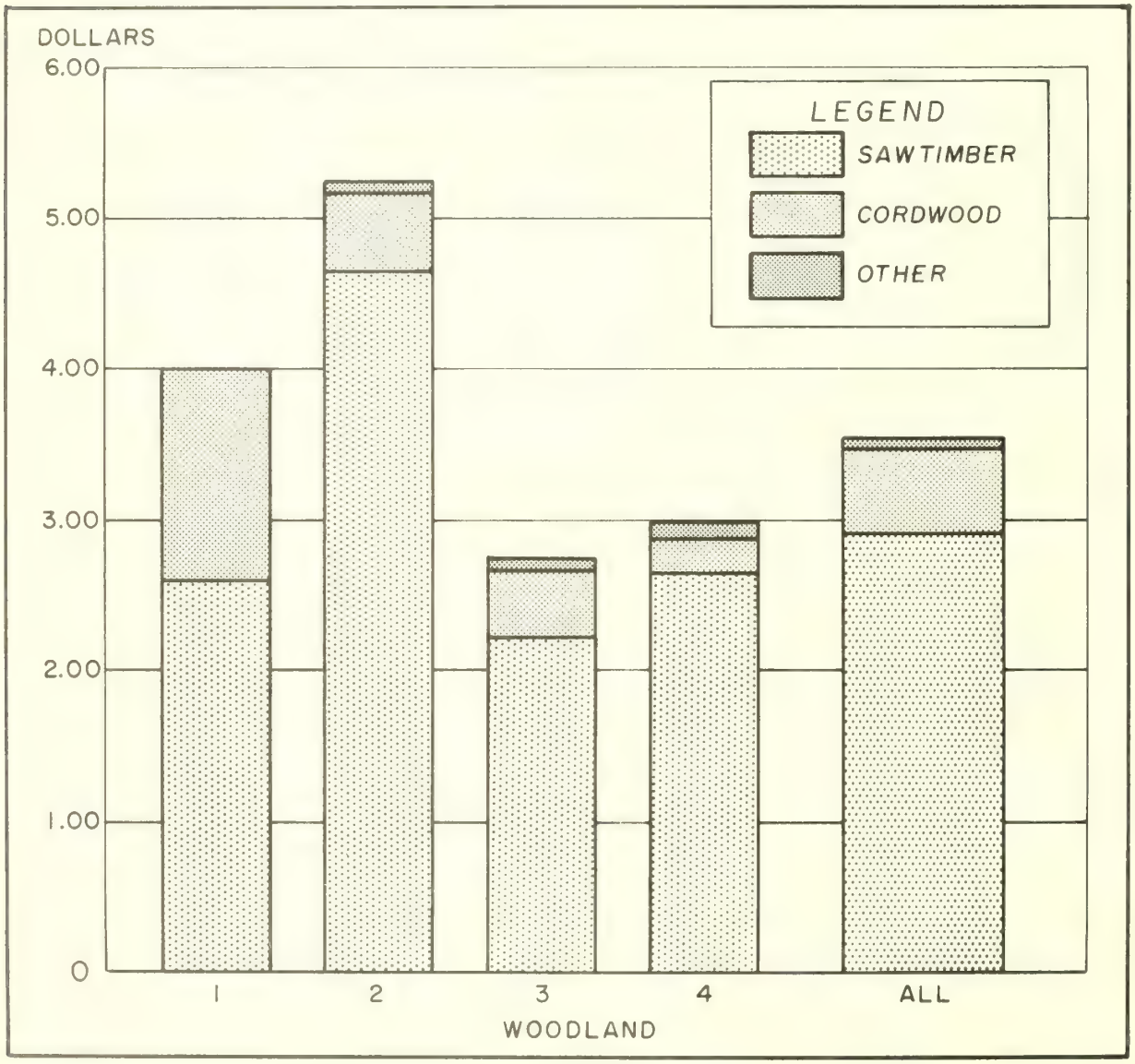


Figure 6.--Stumpage returns per acre per year from farm woods, 1946-1956.

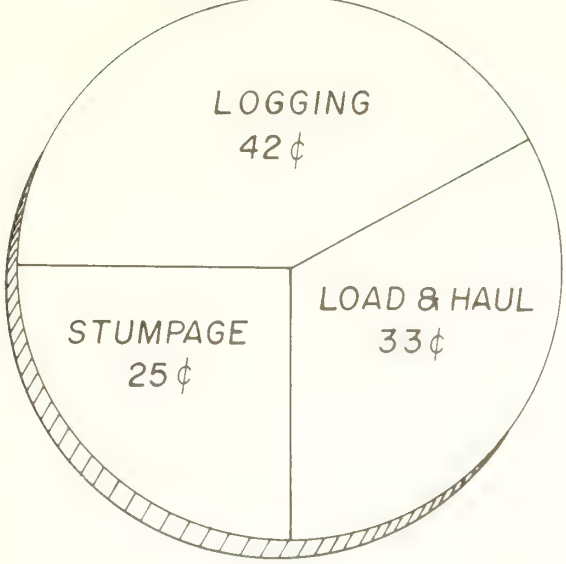


Figure 7.--Division of the market dollar, 1946-1956.

Miscellaneous products such as fence posts, tanbark, and Christmas trees have contributed only a small fraction (2 percent) to the total stumpage returns (fig. 8).

Figure 8.--Christmas trees produced little income during the first 10 years of management but promise to be a very profitable venture in the future as the trees reach desirable size. These are Norway spruces 8 years after planting. Trial plantings of southern balsam have also been set out.

Harvest Time

The average annual harvest input was $5\frac{1}{2}$ man-hours per acre, as shown in table 3. If timber marking and cruising time were added, the total would approximate 1 man-day per acre per year. Cordwood products required most of the time, 60 percent, while the harvest of sawtimber required 36 percent of the listed total, and other products the remaining 4 percent. The high figure for sawtimber from Woodland 2 appears out of line, but no satisfactory explanation for it is known at present.

Table 3.--Harvest time[1] per acre for various forest products

Woodland	Sawtimber	Cordwood	Other products[2]	All
	Hours			
1	1.67	6.14	--	7.81
2	3.13	4.72	0.89	8.74
3	1.68	2.37	.09	4.14
4	1.66	1.67	.13	3.46
Average	1.97	3.26	.24	5.47

1/ Labor shown is time from stump to roadside only, and is a 10-year average.

2/ Includes posts on Woodlands 3 and 4, tanbark on Woodland 2, and Christmas trees on Woodland 3.

Hourly Returns

The difference between roadside value and stumpage value is called conversion return. These returns are shown in table 4 for each of the major products by woodland, based on a 10-year average. The hourly returns are higher for sawtimber than for other products except in Woodland 1, where a large volume of insect-infested pine was harvested as cordwood. The conversion returns divided by the hours required to produce each type of product are known as gross hourly wages, and these too are shown in table 4. Note that they are highest for sawtimber and are about equal for cordwood and other products. Net hourly returns can be approximated by deductions from the gross hourly wages shown in table 4. These deductions, to cover equipment and depreciation costs, are 25 cents per hour for sawtimber and 15 cents per hour for cordwood.

Summary

This 10th year summary shows that the woodlands in general contain about the same basal area, board-foot volume, or cordwood volume as they did in the beginning some 10 years ago. However, the 10 years of management have greatly improved the quality of growing stock. They have also increased the earning power of the stand through the removal of old growth which was mature and earning interest at only a fraction of 1 percent per annum.

The results of 10 years of management show that if a farmer owned timber of similar average size and stocking, he would have obtained a return from the sale of stumpage alone of $3.55 per acre per year, even during the initial management period. And if, in addition, he had done the woods work, he would have tripled his forest income, to about $10 per acre per year.

Furthermore, if he had a truck and could load and haul his forest products to market, he would increase his return another 50 percent--to nearly $15 per acre per year. In this case, he would be selling his labor as he does in marketing wheat or tobacco.

Table 4.--Annual conversion returns [1/] per acre and gross hourly wages [2/]

Woodland	Sawtimber	Cordwood	Other products	All
		Dollars		
Woodland 1				
Conversion returns	2.47	6.50	--	8.97
Gross hourly wages	1.48	1.06	--	1.15
Woodland 2				
Conversion returns	4.66	4.26	0.79	9.70
Gross hourly wages	1.49	.90	.89	1.11
Woodland 3				
Conversion returns	2.23	2.36	.06	4.55
Gross hourly wages	1.33	1.00	.67	1.10
Woodland 4				
Conversion returns	2.16	1.60	.16	3.92
Gross hourly wages	1.30	.96	1.23	1.13
Average				
Conversion returns	2.73	3.18	.23	6.14
Gross hourly wages	1.39	.97	.96	1.12

1/ Conversion returns shown are roadside values less stumpage values.

2/ Net wages can be computed by deducting 25 cents and 15 cents from gross hourly wages for sawtimber and cordwood, respectively; these deductions are to allow for equipment operation and depreciation.

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